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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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See half-page Advertisement page 66, Sept. 8.

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PATENTS AND DESIGNS ACT, 1907.

Notice is Hereby Given that

SIR KENNETH IRWIN CROSSLEY, BARONET, of Crossley Brothers Limited, Openshaw, Manchester, and WILFRED LE PLASTRIER WEBB, of Rostrevor, Hale, Cheshire, Engineers, SEEK LEAVE to AMEND the Specification of Letters Patent No. 2876 of 1915 granted to them for "Improvements in oil fuel injection devices for internal combustion oil engines."
Particulars of the proposed amendment were set forth in the *Illustrated Official Journal (Patents)*, issued on the 6th September, 1916.
Any person, or persons, may give notice of Opposition to the Amendment by leaving Patents Form No. 18 at the Patent Office, 25, Southampton Buildings, London, W.C., within one calendar month from the date of the said Journal.
(Signed) W. TEMPLE FRANKS, P 77
Comptroller-General.

University of Manchester.

PHYSICS DEPARTMENT.

Full particulars of the LECTURE and LABORATORY COURSES in PHYSICS, preparing for both the Ordinary and Honours Degrees, will be forwarded on application to the Registrar. PROF. RUTHERFORD will meet intending Students on Thursday, October 5th, at 10.30 a.m. F 38

The Royal Technical College, GLASGOW.

SESSION 1916-17
BEGINS ON SEPTEMBER 26TH.

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NEW SESSION
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Details of the Classes may be had upon application at the Office of the Institute, or by letter to the PRINCIPAL. F 83

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UNIVERSITY & TECHNICAL DAY & EVENING COURSES in MECHANICAL and ELECTRICAL ENGINEERING commence 26th September, 1916.
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SESSION 1916-1917.

COMMENCING 25th SEPTEMBER, 1916.

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Special terms to those enrolling before 23rd SEPTEMBER.
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R. H. WALPOLE,
Secretary.
Company's Offices,
48, Copthall Avenue, London, E.C.
13th September, 1916. F 84

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The Plant required shall be of the travelling-tower type, self-propelling, with the whole of the machinery for performing all the functions of the Transporter carried on the tower itself and operated by electrically-driven motors.
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All motions of the Plant shall be electrically operated.
The Plant shall be capable of handling coal at the rate of 60 tons per hour, that is to say, at the rate of 40 lots per grab per hour.
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Electrical energy available for operating the Transporter tower will be in form of continuous current at a pressure of 440 to 460 volts.
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Each Tenderer must send in with his Tender, either in cash or by Bank Draft, a deposit equal in amount to 2½ per cent. upon the amount of his Tender, as a guarantee of good faith, and in the event of his Tender being accepted by the Council, his must forthwith increase his deposit to an amount equal to 5 per cent. upon the amount of his Tender, as a security for the due performance of his Contract. This deposit may, if desired, be handed to Messrs. McILWRAITH McEACHARN & Co. PTY., LTD., in which case their receipt for same must accompany the Tender.
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A Teacher is Required, at

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BRACKETS ON STANCHIONS.

By W. T. S. BUTLIN, A.M.Inst.C.E., Wh. Ex., R.Ex.

IN a recent issue of ENGINEERING* the problem of stresses induced by brackets on stanchions of uniform section was dealt with. Graphical methods were adopted, and the more difficult cases considered involved drawing out bending-moment diagrams, obtaining the areas and centres of area of these, and manipulating the latter to ascertain what may be described as the closing lines of the diagrams. The sign of the bending moments presented certain difficulties and required very careful handling. Except in unusual circumstances, therefore, it would appear possible that the elaboration and time necessary would be more than the average man could give the subject.

A simpler and safer way is to attack the problem from the mathematical point of view, which also, incidentally, avoids the sign difficulty inherent in the graphical method.

Now as to the method. For present purposes the forces imposed on a stanchion by a loaded bracket will be taken as one vertical and two horizontal, the two latter being the pull exerted by the top of the bracket and the corresponding thrust from the bottom of the bracket. The vertical force presents no difficulty and will not be further considered in this article. With regard to the horizontal forces, if these are dealt with singly by the ordinary formulæ as applied to beams, it becomes easy to find the shears or reactions and the bending moments induced in the stanchion. This will be done first for the pulling force, then for the thrusting force, the results being visualised by plotting, and then the algebraic sum of the two taken for the final result.

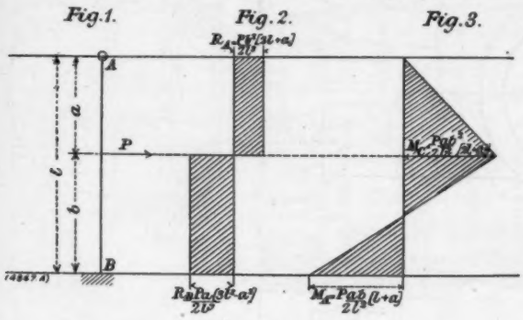
Fig. 1 shows diagrammatically a stanchion of uniform section fixed at the base and hinged at the top. It is acted upon by a single force P. Figs. 2 and 3 give the shears and bending moments at the critical points by means of symbols.

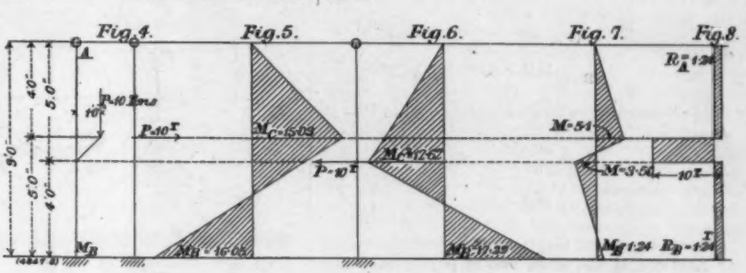
These symbols can now be applied to a numerical example of a bracket fixed to a stanchion. Details of the dimensions and loads are given in Fig. 4. Fig. 5 gives the values of bending moments calculated in foot-tons at the critical points induced by the pull from the top of the bracket. Fig. 6 shows the corresponding moments worked out for the thrust from the bottom of the bracket. Fig. 7 gives the algebraic sum of the two sets of results plotted in the previous Figs. 5 and 6, which, of course, is the solution required. The finding of the reactions or shears presents even less trouble than the moments, and Fig. 8 gives the final solution at once without following through the steps by taking each force in detail.

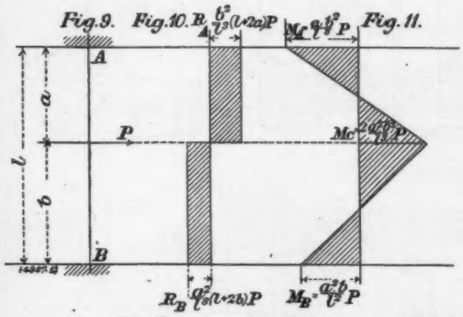
The next case to be considered is that of a stanchion fixed at both ends. Under the action of a single horizontal force the shears and bending moments at the critical points are as indicated by the symbols in Figs. 9, 10 and 11.

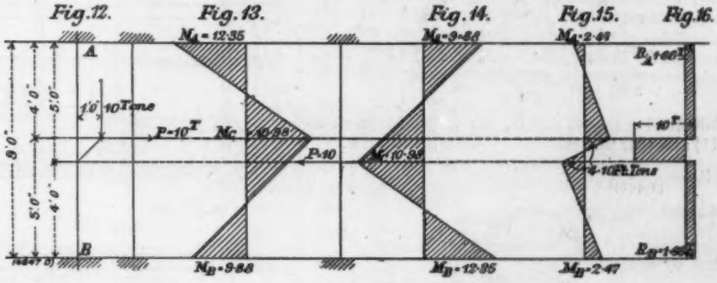
In the application of the above, two examples will be taken in order to illustrate certain variations which occur. Figs. 12 to 16 show the results obtained by applying the symbols to the case of a bracket placed near the centre of a stanchion fixed at both ends. Figs. 17 to 21 show the resulting moments and reactions obtained when the bracket on the stanchion is fixed near the top end.

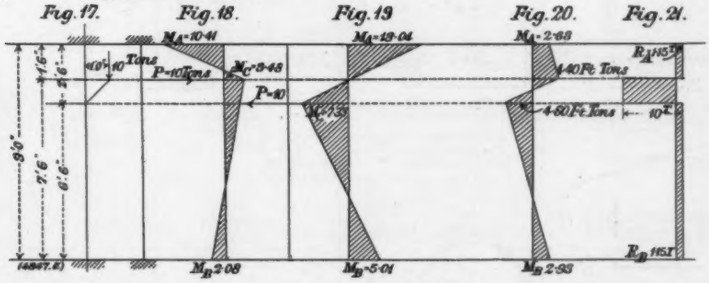
Two features call for attention. If the diagrams of bending moment shown on Figs. 15 and 20 be compared it will be noticed that the result of shifting the bracket from the centre to the top of the stanchion is to cause the bending moment to become reversed and increased. The other point concerns the reactions or shears at the ends of the stanchion. Comparing the respective diagrams shown in Figs. 16 and 21 it is evident that the shifting of the bracket from the centre to the top of the stanchion has caused the reactions at the ends of stanchion to decrease from 1.66 tons to 1.15 tons. This would be further decreased to a minimum of 1.11 tons if the ends of the stanchion were hinged instead of fixed. Conversely, if a stanchion supporting a bracket and hinged at the ends has the ends fixed by some means, the reactions at the ends will be automatically increased. This is a curious fact, but it has escaped the notice of some writers on the subject. A proof of the symbols used in the above workings, when applied to a stanchion fixed at both ends, is attached.











* ENGINEERING, June 23, 1916, page 589.

PROOF.

Consider a beam fixed at the ends and non-centrally loaded. Referring to Fig. 9, take B as origin. Then from B to P we have :—

$$E\,I\,\frac{d^2y}{dx^2} = -R_b\,x + M_b$$

where

E = Modulus of elasticity,
I = Moment of inertia of beam,
R_b = Reaction at B,
M_b = Bending moment at B,
x = Distance of point considered from origin.

Integrate

$$E\,I\,\frac{dy}{dx} = -R_b\,\frac{x^2}{2} + M_b\,x + 0 \quad . \quad (1)$$

Integrate again

$$E\,I\,y = -R_b\,\frac{x^3}{6} + M_b\,\frac{x^2}{2} + 0.$$

At P, $x = b$

$$E\,I\,y_p = -R_b\,\frac{b^3}{6} + M_b\,\frac{b^2}{2} \quad . \quad . \quad (2)$$

Now take A as origin, and measure x as positive towards P, and remember that $\left(\frac{dy}{dx}\right)_p$ will have its sign changed. Then by analogy we get :—

$$E\,I\left(\frac{dy}{dx}\right)_p = R_a\,\frac{a^2}{2} - M_a\,a \quad . \quad . \quad (3)$$

and

$$E\,I\,y_p = -R_a\,\frac{a^3}{6} + M_a\,\frac{a^2}{2} \quad . \quad . \quad (4)$$

Equating equations (1) and (3), when x is put equal to b in the former, we have :—

$$-R_b\,\frac{b^2}{2} + M_b\,b = R_a\,\frac{a^2}{2} - M_a\,a$$

$$R_b\,b = -R_a\,\frac{a^2}{b} + M_a\,2\,\frac{a}{b} + 2\,M_b \quad (5)$$

Equating equations (2) and (4)

$$-R_b\,\frac{b^3}{6} + M_b\,\frac{b^2}{2} = -R_a\,\frac{a^3}{6} + M_a\,\frac{a^2}{2}$$

$$R_b\,b = R_a\,\frac{a^3}{b^2} - M_a\,3\,\frac{a^2}{b^2} + 3\,M_b \quad . \quad . \quad (6)$$

Further, it is obvious that

$$R_b\,b - M_b = R_a\,a - M_a$$

$$R_b\,b = R_a\,a - M_a + M_b \quad . \quad . \quad (7)$$

Subtracting 3 times equation (5) from 2 times equation (6) we get

$$-R_b\,b = \frac{a}{b}\,R_a\left(2\,\frac{a^2}{b} + 3\,a\right) - 6\,\frac{a}{b}\,M_a\left(\frac{a}{b} + 1\right) \quad (8)$$

Subtracting 2 times equation (7) from equation (5) we get

$$-R_b\,b = -R_a\left(\frac{a^2}{b}+2a\right)+2M_a\left(\frac{a}{b}+1\right) \quad (9)$$

Multiplying by $3\,\frac{a}{b}$

$$-3aR_b = -3\,\frac{a}{b}R_a\left(\frac{a^2}{b}+2a\right)+6\,\frac{a}{b}M_a\left(\frac{a}{b}+1\right)$$

And adding equation (8) to this we get

$$-R_b\,(b+3a) = \frac{a}{b}R_a\,(-\frac{a^2}{b}-3a) \quad . \quad (10)$$

For R_b write $P - R_a$, then

$$(R_a - P)\,(b+3a) = R_a\left(-\frac{a^3}{b^2}-\frac{3a^2}{b}\right)$$

$$R_a = \frac{b^2\,P\,(b+3a)}{b^3+3ab^2+3a^2b+a^3}$$

$$R_a = \frac{b^2\,(b+3a)}{(b+a)^3}\,P \quad . \quad . \quad . \quad . \quad (11)$$

or

$$R_a = \frac{b^2\,(l+2a)}{l^3}\,P.$$

Either by analogy or by putting R_a equal to $P - R_b$ we get

$$R_b = \frac{a^2\,(a+3b)}{(a+b)^3}\,P \quad . \quad . \quad . \quad (12)$$

or

$$R_b = \frac{a^2\,(l+2b)}{l^3}\,P.$$

These equations (11) and (12) give the shears or reactions at the ends, and it is necessary now only to investigate the bending moments.

Equation (9) is

$$2M_a\left(\frac{a+b}{b}\right) = R_a\,\frac{a^2+2ab}{b} - R_b\,b$$

$$2M_a = R_a\,\frac{a^2+2ab}{a+b} - R_b\,\frac{b^2}{a+b}$$

Substituting for R_a and R_b the values in equations (11) and (12) we get

$$2M_a = \frac{P}{(a+b)^3}\left\{\frac{(a^2+2ab)\,b^2\,(b+3a)}{b+a} - \frac{b^2a^2\,(a+3b)}{a+b}\right\}$$

Whence

$$M_a = \frac{a\,b^3}{(a+b)^3}\,P \quad . \quad . \quad (13)$$

And by analogy

$$M_b = \frac{a^3\,b}{(a+b)^3}\,P \quad . \quad . \quad . \quad (14)$$

Again, at any point x

$$M_x = -R_b\,x + M_b.$$

Substituting for R_b and M_b and putting $x = a$ we get

$$M_p = P\left\{-\frac{a^2\,b}{b^3}\,(a+3b)+\frac{a^3\,b}{b^3}\right\}$$

Whence

$$M_p = -\frac{2\,a^3\,b^3}{b^3}\,P \quad . \quad . \quad . \quad (15)$$

These equations, (13), (14) and (15), complete the information about the bending moments. The case of a stanchion fixed at one end and hinged at the other can be derived in part from the above and will not be given here.

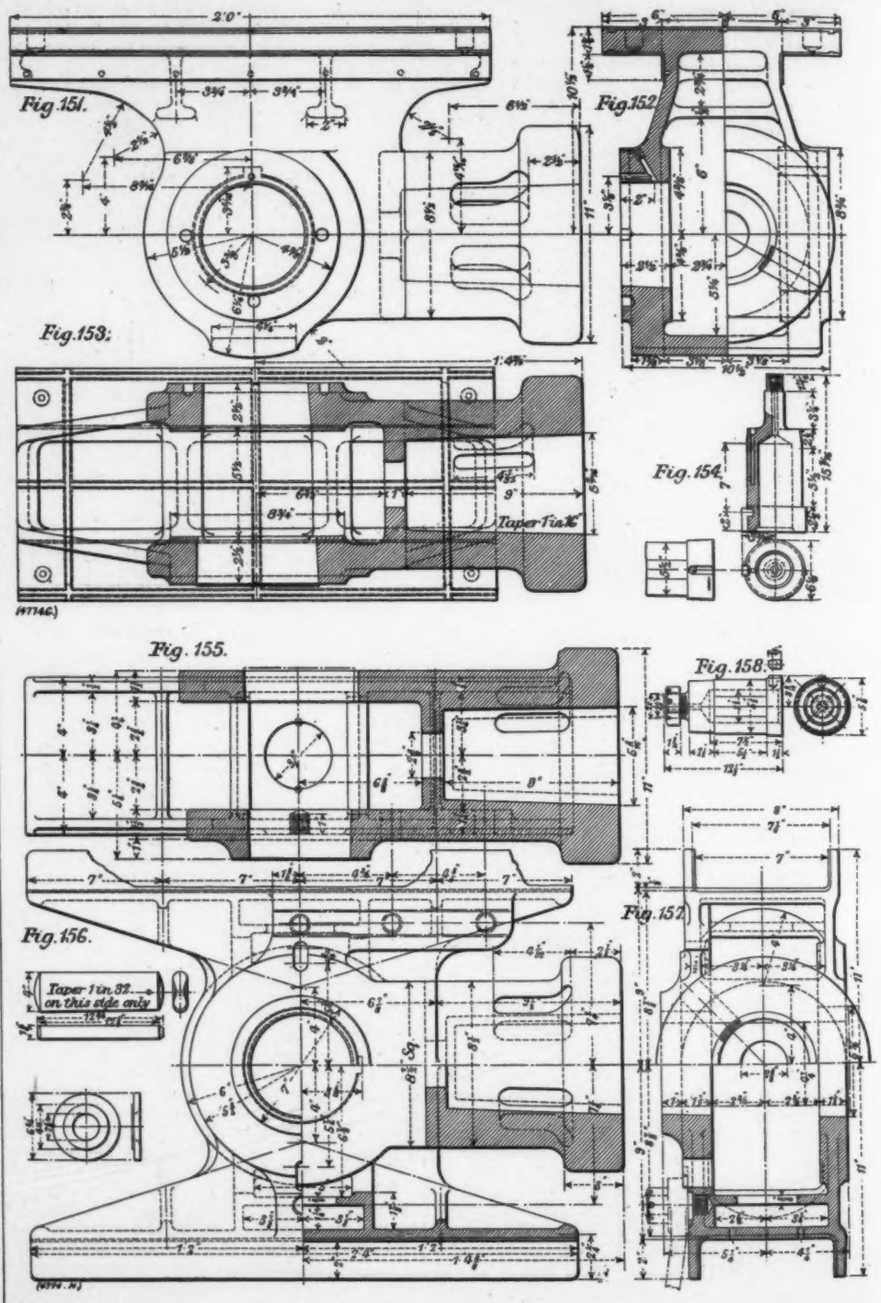
HIGH-POWERED LOCOMOTIVES FOR THE PENNSYLVANIA RAILROAD.

(Continued from page 196.)

FIGS. 119 to 122, on Plate XXIV, published with the present issue, show the cylinders of the "L 1 S" type of locomotive, these being really typical of the two classes with which we are dealing, the cylinders for the "K 4 S" class, however, being made for a stroke of 28 in., while in the case of the "L 1 S" class the stroke is 30 in. A view of these cylinders, prepared from a photograph, is also given in Fig. 167, on page 256. The two cylinders are parted on the centre line of the engine, where they are united by a strongly bolted joint. As will be seen from the section, Fig. 120, they are provided with ample attachments to the smoke-box and the frames, while, in addition to the bolted connections to the frames, keys are used. The valve chambers are, as will be seen, situated above the cylinders.

The cylinders are of cast iron, and are fitted with liners ¾ in. thick, these liners being of a harder grade of metal than the body of the cylinder casting. It is now the practice of the Pennsylvania Company to fit liners to all cylinders when new, it having been found to be a comparatively easy matter to renew such bushings in case of wear. Cast-steel cylinders have been tried experimentally, but on account of the greater cost of these castings and the small amount of trouble experienced with cast-iron cylinders the use of cast-steel cylinders has not been perpetuated. The cylinder heads, however, are made of cast steel, the change from cast iron, formerly used, being intended to overcome trouble due to broken cylinder heads. It was found that owing to improper handling water would occasionally be allowed to get into the cylinders, causing a broken cylinder head, and in at least one case personal injury resulted. The front cylinder heads for both the types of engine with which we are dealing are shown by Figs. 123 and 124, on Plate XXIV, while Figs. 125 and 126 show the rear cylinder heads for the "L 1 S" type only, that type being, as we have already described, fitted with double guide bars.

Both types of engine are fitted with piston valves 12 in. in diameter. Tests made by the Pennsylvania Railroad Company with various sizes of valves for different sizes of cylinders have shown that when using superheated steam an 8-in. valve is satisfactory for any cylinder up to 20½ in. in diameter, and that a 12-in. valve is satisfactory for any cylinder up to, and including, 32 in. in diameter. Figs. 127 to 130, on Plate XXIV, show a 12-in. valve of a design which is now in use on a large number of the Pennsylvania locomotives. It will be seen that the valve spool is built up of three pieces, the centre portion being a 5½-in. seamless steel tube, while the ends of the spool are made of pressed pieces of boiler plate, the parts being electrically welded together. The valve "spiders" are drop forgings and are purposely made as light as possible, consistent with the required strength. The rings are of the anchored L type, and their details are plainly shown by the sections, &c., given in Figs. 127 to 130. The valve complete, without the valve stem, weighs, for the classes of locomotive under notice, 119 lb.



In both the classes of locomotives with which we are dealing the piston rods are extended through the front cylinder heads, suitable front guides and cross-heads being provided. The rods are hollow, as shown in Figs. 131 to 134, on Plate XXIV. The rod is first forged into the form shown in Fig. 131, and a 2½ in. hole is then drilled entirely through it. After this is done the rod is reduced at the front and back ends and at the piston seat by the use of a hydraulic forging machine, the rod being turned a part of a revolution between the successive applications of pressure. Next, the rod is heat-treated, and is then turned to the finished dimensions as shown in Figs. 132 to 134.

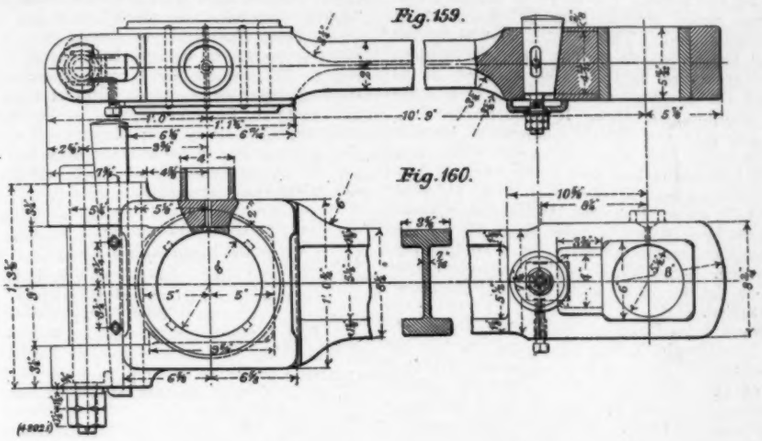
The adjoining Figs. 135 to 137 show the cross-head attached to the front end of the piston rod. This consists of a cylindrical bronze bearing which is held in place by a washer and nut, and which is fitted with a suitable key (see Fig. 137), so that it can be rotated on the piston rod and fixed in four different positions, thus affording four different wearing surfaces. The alternative grooves for receiving the key are shown in Fig. 135. The guide in which this cross-head works is shown by Figs. 138 to 140, Plate XXIV. It is bolted to the front cylinder head, and is provided with a suitable cover to keep dirt from the bearing surfaces.

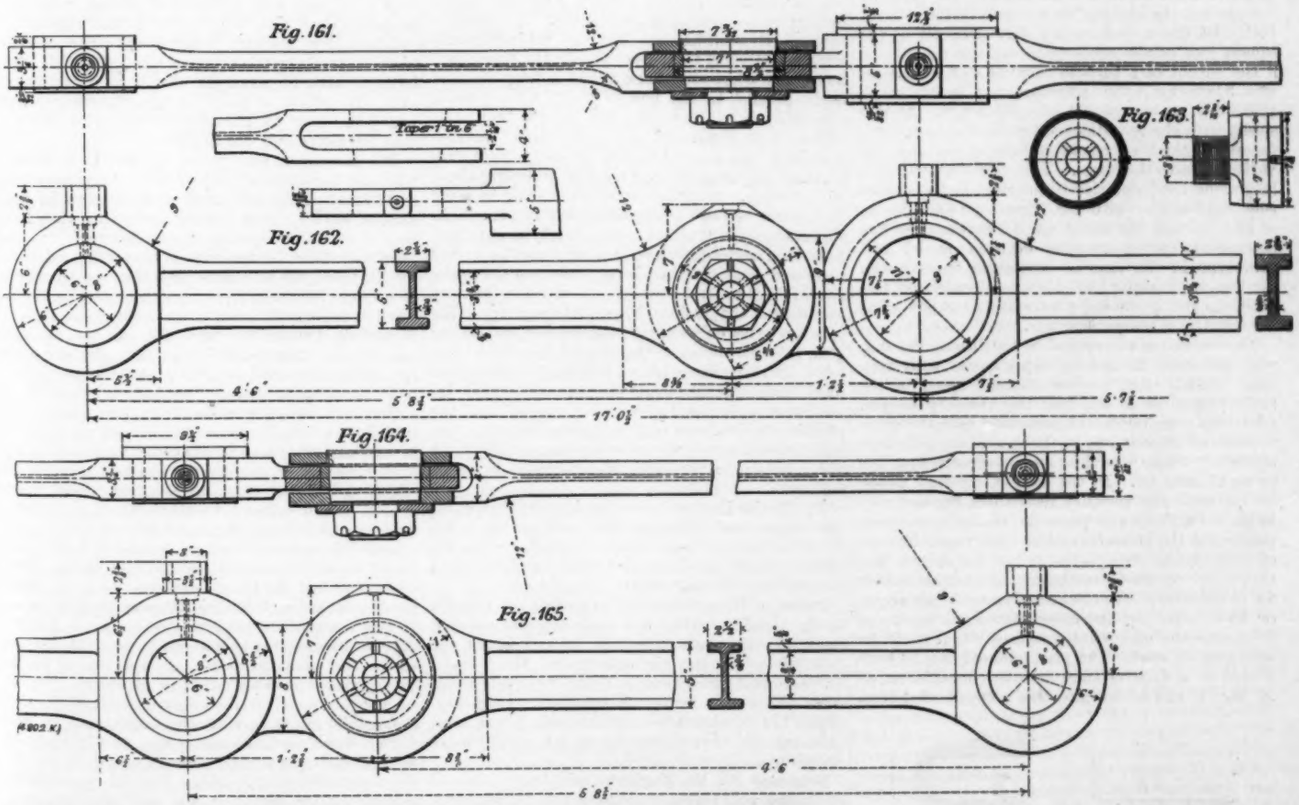
The pistons used are of rolled steel, and the design is shown by Figs. 141 and 142, on Plate XXIV. The piston body is turned $\frac{3}{16}$ in. smaller in diameter than the cylinder, its weight being supported by the rod. The enlarged detail sections annexed to Figs. 141 and 142 show clearly the construction of the piston rings used. The connection between the piston and its rod is made solely by shrinking the former on the latter, a nut, with lock washer, being added merely to give additional security.

Figs. 143 to 150, on Plate XXIV, show the valve-stem cross-heads and guides. The cross-head, it will be noted, is very light, it being made of heat-treated carbon steel, and all superfluous metal being removed. The cross-head guide (Figs. 147 to 150) is self-supporting, it forming part of the steam chest head, which also contains the stuffing-box for the valve stem. As shown in Fig. 147, the valve stem guides are fitted with phosphor-bronze liners, on which the cross-heads move. Each liner is fixed in position by a bolt, as shown in the section, Fig. 147, Plate XXIV.

In dealing (on page 195 *ante*) with the main frames and some of their attachments, we mentioned the difference between the arrangements of guide bars adopted in the two classes of locomotive with which we are dealing. We now give, on the opposite page, engravings of the corresponding cross heads. Figs. 151 to 154 show the type of cross-head used for the "K 4 S" class of engine, in which, it will be remembered, a single three-part guide is used above the piston rod. In the "L 1 S" type of engine double guides are used, and the design of the corresponding cross-head is shown by Figs. 155 to 158, on page 244. Both cross-heads are of cast steel, and they have been made as light as possible consistent with obtaining the desired strength. The details of the cross-heads and their pins are fully shown in our engravings. The view of the front end of an engine of the "K 4 S" class which we give in Fig. 166, on page 256, and the view of the cylinders, guide-bars, &c., of engines of the "L 1 S" class given in Fig. 167 on the same page, will show clearly the differences in the designs of the guide-bars and cross-heads, to which we have drawn attention above.

Figs. 159 and 160, on the present page, show the connecting rods of the "L 1 S" class of engine, these rods being typical of Pennsylvania Railroad practice. In designing the connecting rods for the classes of engine under notice, it has been the object to make these rods the weakest point in the driving gear. Thus these rods, as proportioned, would bend laterally under less load than would suffice to break off a cylinder head, to fracture a piston rod or main crank-pin, or to destroy the connection between the piston rod and the cross-head. In these designs the factor of safety in the connecting rod for lateral bending is 3½, based upon the maximum steam pressure on the pistons. The experience on the Pennsylvania Railroad is that occasionally a boiler is filled too full of water, and some of this water gets into the cylinders, the result being a bent connecting rod, which can be readily straightened when the engine arrives at its terminal. This is far preferable to a broken part. To relieve the excessive pressure due to an accumulation of water in the cylinders, various water-relief valves





have been tried on the Pennsylvania Railroad, and further experiments are being made, but up to the present no really satisfactory valve, meeting all the requirements, has been evolved.

The coupling rods for the "K 4 S" class of engine are shown in detail in Figs. 161 to 165, on page 245. The design and dimensions are clearly shown by the views referred to, but attention may be called to the large size of the knuckle-joint pins and to the slight lateral flexibility given by the form of the jaw and tongue of each knuckle.

(To be continued.)

THE BRITISH ASSOCIATION.

(Continued from page 232.)

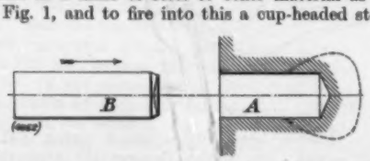
SECTION G.—ENGINEERING.

At the meeting of the section on Thursday morning the first paper taken was contributed by Dr. T. E. Stanton, F.R.S. This paper, which we publish in full on page 266 of this present issue, dealt with

The Principles of Similitude.

In declaring the discussion open the president, Mr. Gerald Stoney, said that the principles of similitude were capable of very extensive use in practical engineering work. As an example he might point out that if similar steam turbines were designed so that the blade stress and the ring stress on drum were constant, and with blade heights proportional to the respective diameters, the dummy leakage and the blading losses would be the same in both, and the outputs would vary inversely as the square root of the revolutions per minute. Thus, if the output of a turbine running at 3,000 r.p.m. was 3,000 kw., the corresponding speed for a 12,000-kw. turbine would be 1,500 r.p.m. At this speed, with the conditions assumed, the centrifugal forces on the two would be the same, and the various losses the same. This law was valuable in passing from one size to another, and a similar rule applied (but with less accuracy) to the design of alternators. He would ask the author if he had considered the connection between model and prototype in the case of cavitation experiments. Sir Charles Parsons had done much work on this problem, and it would be interesting to know what the true law of comparison was.

The discussion was opened by Sir Charles Parsons, who said that in making experiments with very small models the "corresponding" speed of the model might be so low that the viscosity became relatively more important compared with the other resistances than it was in the case of the full-sized machine. There was thus a scale effect which had to be allowed for. In the case of capillary tubes, for instance, the viscosity resistances became very large. Similarly with gases the viscosity was independent of the pressure, and at high vacua became of predominant importance, and it was on this fact that the Gaede pump was based. In connection with an investigation into the actual pressure per sq. in. on knife edges, he had made some experiments to determine the maximum pressures which could be produced on steel. The plan followed was to bore a hole in a mass of steel or other material as at A, Fig. 1, and to fire into this a cup-headed steel



projectile B, which just fitted the hole. The pressure produced was proportionate to the square of the velocity of the projectile and was independent of its hardness. At a pressure of 600 tons per square inch the volume of a mass of steel was diminished 20 per cent., and were it not for this diminution in bulk the pressures attained would be nearly infinite. Actually he had got pressures of 1,000 to 3,000 tons per square inch. The projectile flowed into the metal at the bottom of the hole, filling a cavity somewhat of the form indicated by the dotted lines. In some of the experiments the projectile had been fired through different materials, thus subjecting them to the intense pressures stated. In the case of white-hot carbon the effect of this extreme pressure was *nil*. Very little was known about screw propellers. In his own experiments with a cavitation tank he obtained the desired effect at low speeds by removing the pressure of the atmosphere from the surface of the water. These lower speeds were convenient as requiring less power, and simplifying the use of an intermittent beam of light for illuminating the model. The effect of viscosity was, however, much greater than it would be at the higher speed. This was a drawback, but he had had to put up with it. His observations had thrown some light on the question as to whether the acceleration of the fluid took place before or behind the screw. It appeared that both views were true, and that the minimum diameter of the flux was a little abaft the screw. Some very curious phenomena had been noted which he was now investigating. If cavitation took place in front of the screw, then when the hollows collapsed enormous local pressures were developed on the blade surface, amounting to 10, 20 or 30 tons per square inch. Some day, no doubt, a window would be cut in the skin of an actual ship and the screw itself studied.

Professor John Perry said that a long time ago, when Lord Rayleigh first announced his law of comparison, the speaker had suggested that the flight of projectiles might be studied by models fired through water, the motion being watched through a glass window. Save Sir George Greenhill, no one seemed to have studied what the actual motion of a spinning projectile was. If fired in a vacuum it was known that the projectile axis remained parallel to the tangent to the trajectory, but under what conditions would it keep its nose fairly parallel to the line of flight when passing through air? Greenhill had shown that this depended on the length of the projectile. Airmen who had seen many howitzer shells in flight told him that they seemed to go anyhow, tumbling about in every way. If model experiments could be made with water as the surrounding fluid, and the flight cinematographed, valuable data might be obtained. In making model experiments on fluid friction he had suggested years ago the plan of anchoring the model and letting the fluid flow past it, much in the way now done at the National Physical Laboratory. His idea was to use exceedingly small models, and he had gone into the theory of the subject in order to find what limit to the scale of reduction feasible was fixed by the capillarity and viscosity of the fluid. He had come to the conclusion that it was not until the models were reduced to 1 in. in length that errors due to these factors would be serious, and hence the 1-ft. models he proposed to use would be satisfactory.

Sir Charles Parsons, rising again, said that in his own experiments discrepancies of 17 per cent. due to these factors were observed when the results obtained with a 3-ft. model were compared with those of the full-sized ship.

Professor Horace Lamb, who spoke next, referred to the wobbling of a rifled projectile and asked if there was any sufficient basis for calculating the distribution of the air pressure on the surface. Theoretical hydrodynamics broke down altogether when eddies were formed in the fluid. Lord Rayleigh's law of comparison would hold, it was true, provided the investigator really got similarity of conditions.

Professor W. M. Thornton said that a law of similarity was regularly employed in getting out a "line" of electrical machinery.

Professor C. H. Bulleid said that he had found one law of comparison very convenient in making Brinell tests. The standard size of ball for this test was 10 mm. Not being able to get these he used $\frac{3}{4}$ balls, reducing the results to the standard 10 mm. size. By the law in question, when two balls were driven down to corresponding depths the load needed would be proportional to the square of the diameter of the balls, and the diameters of the depressions would be proportionate to the ball diameters. He had tested the law on a series of balls from $\frac{1}{4}$ in. up to 3 in. in diameter. In discussing the results he had plotted $\frac{\text{load}}{[\text{dia.}]^2}$ against $\frac{\text{diameter of impression}}{\text{diameter of ball}}$. The results came out very well so long as the plate used was not so thin that the depression came through to the other side.

In reply, Dr. Stanton said he was glad to learn that the principle of similitude was being practically used in machine design. As regarded experiments on projectiles, it was necessary to go to velocities exceeding that of sound, and steps, in which Sir Charles Parsons was helping, were being taken to employ such velocities, which had not been used anywhere yet. In respect to experiments on the flight of projectiles we were far behindhand in this country. There was a fine laboratory engaged in such researches at Berlin, and excellent work had also been done by the Bureau of Standards, Washington. He was hoping to set up a model range at Teddington, but it was impossible to make experiments in water, as it was necessary to adopt velocities in excess of the speed of sound.

Standardisation.

Mr. C. Le Maistre next read a paper on "Standardisation and its Influence on Engineering." This was reprinted in our last issue, page 240. A foreword was to have been contributed to this by Sir John Wolfe Barry, to whom in the main is due the credit for the inception of the British Standards Committee. Owing to press of other work, Sir John was, however, unable to make his promised contribution.

In declaring the paper open for discussion the chairman said the author had shown what an immense deal had been done in the matter of standardising machine components. For foreign trade, interchangeability was most essential. All lamp sockets, for example, should be interchangeable. He would be glad to know, moreover, what had been done to standardise the screw threads used for motor cars and bicycles.

The discussion was opened by Mr. C. H. Merz, who said it would be impossible to exaggerate the importance of the subject of the paper, and he was glad to have so clear a statement as to what had been done. The securing of interchangeability was most important, particularly in connection with our foreign trade, but still more important was the effect of standardisation in reducing manufacturing costs. The advertisement value of the work of the British Standards Committee was also of the utmost importance. Anyone who had used the standard specifications knew how greatly they facilitated the ordering of apparatus and equipment generally.

This was especially valuable in connection with customers in the Dominions or abroad when taken in conjunction with the admitted high quality of British work. It was not too much to say that, if widely distributed, these specifications would prove a most useful adjunct to other efforts to extend trade, equal to anything to be expected from any conceivable reform in our consular service. He hoped the main committee would take special steps to arrange that the specifications would be available to all possible users at the cheapest possible price. In this country the price was considerable, but he did not see why they should not be available abroad at the cost of a few pence, or a shilling at most. The advertising value would be enormous. So far as the electrical trades were concerned it was impossible to exaggerate the importance of the work. The electrical industry was one of the newest in this country and had suffered enormously from the want of standardisation. Carried to extremes, standardisation would, it was said, stop progress, but the reverse was true so far as British trade was concerned. He hoped the result would be that fewer firms would make a large range of different types. It was ridiculous that the 40 to 50 different sizes of electric motors required for equipping works should all be made by each of 40 to 50 firms, often in twos or threes. The increased cost was enormous. He could confirm what had been said about the broad-minded attitude of the Admiralty. Mr. Wordingham, the head of the electrical department, might have taken a high-handed position, but instead he had fallen in with the proposals made in a way that might well be imitated by those in charge of much smaller undertakings. Dr. Glazebrook had also rendered invaluable service.

Sir Charles Parsons said that he quite agreed with Mr. Merz and with the chairman on the value to trade of standardisation, but there was one factor in operation abroad which had a very important influence in promoting the process. The commercial banks, with their staffs of experts, would not lend money to traders unless the firm appeared efficient and likely to succeed. This brought great pressure on manufacturers to make them specialise in articles to the production of which their works were best suited, and had a very wide effect. At present in this country a manufacturer requiring money for developments found it difficult to get and might be forced to go to London, where no one knew him, and so get it only at ruinous rates. Commercial banks would, moreover, do much to suppress the fraudulent promoter, who would not care to face the limelight of an investigation by experts. The cleansing effect due to this would be enormous. In America a commercial bank had already been started with a capital of 10 millions. In the old days in this country matters were not so bad. The directors of the private banks knew everybody in the district and lent according to this knowledge. The formation of the joint stock banks had led to the provision of money needed for industrial developments getting largely into the hands of solicitors. He hoped that commercial banks would be established here before long, and was sure that their establishment would have a great effect in promoting standardisation.

In reply, Mr. Le Maistre said that they all realised that standardisation was practicable without necessarily stultifying progress and preventing invention. He quite agreed that the publication of the specifications at a lower price would be valuable, but at present this was impracticable. He hoped, however, that arrangements might be made by which they would be at the service of our consuls abroad. The American Society for Testing Materials, he might note, was having its standards translated into Spanish, and it was intended to sell them at 25 cents a copy.

Lubrication.

Mr. H. T. Newbigin then read a paper entitled "Pressure Oil Film Lubrication." We re-print this communication in full on page 264.

Before calling on Sir Charles Parsons to open the discussion, Mr. Stoney said that they were much indebted to the author for his description of this most interesting development of Osborne Reynolds's work of 1886 on the properties of viscous fluids. He might note that 400 lb. per square inch was by no means the limit of the pressure permissible on Michell blocks. He had himself run such blocks under loads of 4,000 lb. per square inch at rubbing speeds of 53 ft. a second, and in America pressures as high as 9,000 lb. per square inch had been attained. Even at this limit the oil film held; it was the white metal which failed. It was evident, therefore, that enormous pressures could be carried. He thought the application of the principle to journal bearings might revolutionise them as it had done the design of thrust blocks. Nearly all turbine-driven ships were now fitted with blocks of the type described. In such cases there were special difficulties in running with the old-fashioned multiple-collar thrust blocks, as the even turning moment of the turbine did not give the same facilities for the introduction of oil as arose from the variable motion characteristic of the reciprocating engine.

Sir Charles Parsons said he did not think that he could add much to what was set forth in the paper. No doubt the old thrust block was a thing of the past. It was extraordinary how well the new type ran. He did not think he had had a single instance of trouble, whilst with the old type there were continual difficulties, and in addition there was a substantial waste of power amounting to some 5 per cent. in the case of a cargo boat. He was inclined to doubt whether the application of the principle to journal bearings would have much of a future. He thought it would be difficult to secure an even distribution of the load between the numerous parts.

Professor R. L. Weighton, who followed, asked what happened when the motion was reversed. He thought that the efficiency would then fall off greatly, and asked whether it would be right to say that the principle was inapplicable to guide bars because the rapid reversal of the direction of the load interfered with the proper distribution of the lubricant.

Mr. C. H. Merz said that he had met Mr. Michell in Australia and would like to express his appreciation of the work done, which was of the greatest importance, and was being applied to all types of turbine machinery. He asked whether the journal type had yet been applied in practice to steam turbines.

In reply, Mr. Newbigin said only two points requiring an answer had been raised. Professor Weighton asked whether the system was applicable when shafting had to be run in reverse directions. Well, as a matter of fact, the blocks would work properly even if centrally pivoted, or indeed even if pivoted a little in front of the centre. Where a shaft was required to run reversed as well as forward, the practice was either to use centrally pivoted blocks or to make alternate blocks suitable for motion in opposite directions. The film of oil being thickest for the block which was favourably pivoted, the load came practically wholly on these. Though the position of the pivot could thus be varied considerably, the rise of temperature was least when the pivot was behind the centre. The fact that the block would run when centrally pivoted was due to the fact that, owing to its rise of temperature in passing between the surfaces, the viscosity of the lubricant fell off from front to rear and the trailing edge dropped accordingly. As to the lubrication of guides, this really depended on the Michell effect. The fit at the crosshead pin being a little slack, the guide tipped a little in the proper direction with each reversal of its motion. In reply to Mr. Merz he might say that Michell journal bearings were in successful operation in Australia on the vertical shafting of centrifugal pumps. In this country it was proposed to use them for marine shafting. The experiments described in his paper were still in progress, and it was intended to push the rubbing speed up to 200 ft. per second. So far, no trouble had been experienced in getting an even distribution of the load between the pads.

Electrical Ignition.

Professor W. M. Thornton next read a paper on the "Influence of Pressure on Electrical Ignition." In this paper the author described experiments on the ignition by sparks of a mixture consisting of 9.5 per cent. of methane with air, this being the proportion which just secures complete combustion. Two methods of producing the spark were investigated. In the one case the spark gap formed part of the secondary circuit of an induction coil, and the strength of primary current, which just sufficed to secure ignition, was observed when the pressure of the explosive mixture was varied from half an atmosphere absolute up to a pressure of 90 lb. per square inch above atmosphere. Starting from the lower limit, the ease of ignition increased whilst the pressure rose from half an atmosphere absolute up to a pressure of about two atmospheres or more. With a further rise of pressure, however, the ease of ignition diminished, and for pressures of 80 to 90 lb. above atmosphere the current required to secure ignition was more than double the minimum value. A curious feature of the phenomenon observed was that the curve plotted with the igniting current and the pressure of the mixture as ordinates was not a continuous curve, but had a stepped character. In a further series of experiments the spark was produced by means of a condenser discharge. It was found that for all pressures between half an atmosphere and one atmosphere ignition was secured with 6 microfarads charged to 150 volts; whilst ignition was not secured at pressures less than the lower limit named. With pressures above the atmospheric the ease of ignition was increased for all the pressures tried, whilst when the spark was produced by an induction coil ignition was materially more difficult at high pressures, as already stated above.

Operating Diesel Engines with Low Compressions.

A paper by Professor W. H. Watkinson describing "Some Experiments on the Possibility of Working Diesel Engines with Low Compression Pressures" followed, and after this came a report from the Committee on

Gaseous Explosions

stating that owing to the pressure of war work little or nothing had been done by them during the year and asking to be reappointed.

Professor Watkinson's paper described a very simple and ingenious method of avoiding the excessive pressures which are liable to be developed during the starting up of a Diesel engine. The author showed a continuous indicator diagram taken from a Diesel engine during the operation of starting it. After making the initial revolution by means of the compressed air supply the engine ran for seven or eight revolutions before ignition occurred, although fuel had been fed in on each admission stroke. When ignition finally did occur the diagram obtained was to some extent of a gas-engine character rather than of the Diesel type. Thus the maximum pressure rose on ignition to between 800 and 900 lb. per square inch, and then fell rapidly, whilst once the engine was working normally the maximum pressure was only 500 to 550 lb. per square inch, and was thus sustained for a considerable fraction of the stroke. The abnormal pressures which are liable to be developed in this process of starting make it necessary, the author said, to use heavier scantlings for the engine than would otherwise be required. His method of eliminating them is to throw out of action, during the operation of starting, the gear for mechanically and positively opening the air-admission valve. The latter becomes, therefore, for the time being an automatic valve. The resultant wire-drawing due to the stiffness of the spring with which the valve is fitted is such that at the end of the stroke the pressure of the indrawn air is only about 7 lb. absolute. Its temperature, however, is practically the same as if the valve had been fully opened in the usual way. On the return stroke the temperature attained, being dependent merely on the ratio of the compression and not on the actual compression pressure, is the same as if the valve had been worked in the normal way. The charge of fuel sprayed in is therefore ignited without difficulty, although the pressure attained is halved. We hope to publish this paper in full in a later issue.

The discussion on all three was taken together.

The first speaker was Mr. Dugald Clerk, who said he had been much interested in Professor Thornton's paper. Those who had experimented on gaseous explosions knew that in certain cases it was possible for a spark to pass through a very inflammable mixture without firing it, but when this happened previous experimenters had merely increased the intensity of the spark without investigating the matter further. Professor Thornton had been the first to tackle the question quantitatively, determining the conditions in which the mixture would inflame or not inflame.

He had himself observed that with very dilute mixtures an explosion might be started, but the flame flickered out before the pressure rose more than 4 or 5 lb., and a subsequent analysis of the contents of the explosion vessel showed that a large proportion of the gas present remained unconsumed. One point he had observed, but which remained unexplained, was the curious character of the pressure curve when the combustible was a hydrocarbon. The pressure first rose rapidly—then the rate of rise slowed down—and then increased again. In describing this many years ago he had suggested that the rate of combustion accelerated until the flame extended throughout the whole volume of the vessel, but that the temperature was at this point still below the maximum. This conclusion was disputed at the time, but Professor Hopkinson had found experimentally that at the moment at which the flame completely filled the whole vessel the pressure was still 20 per cent. below its final maximum value. The peculiarity described was always present when the combustible was a hydrocarbon, but he had never observed it with hydrogen or carbon monoxide. He suggested that Professor Thornton should repeat his experiments, using a much larger explosion chamber, as small ones were very tricky, and try also the effect of temperature. Coming to Professor Watkinson's paper, he thought no one would expect the ignition of the fuel in a

Diesel engine to depend upon the compression pressure. The governing factor was not this, but the range of the compression, which in the Diesel engine was usually 13 to 1. By throttling the suction in the way explained by the author the range of compression was unaltered, merely the density of the charge being changed, and he saw no reason why effective ignition should not be obtained even when the maximum compression pressure amounted to only two atmospheres. In answer to a question from Sir Charles Parsons, Mr. Clerk said that, so far as was known, the gas inflamed a little more readily at higher pressures.

Professor Petavel, who spoke next, asked by what criterion was the efficiency of magneto ignition to be judged, by the total discharge, by the voltage, or by the current necessary to just avoid misfires. He might add that the variation of the ignition point with pressure, to which reference had been made, was a very interesting one. He had made experiments on the ignition of almost non-inflammable mixtures at very high pressures, working with two different kinds of discharge. The pressures used were as high as 2,000 to 3,000 lb. per square inch, and in these conditions the flame was difficult to start by means of an alternating-current discharge, but combination took place distinctly more easily than at atmospheric pressure. He had next used a make-and-break spark, and here again there was, with a given energy expended in the spark, more combination as the pressure increased. At very high pressures, however, the insulation resistance of the gas became so high that it was difficult to get a spark to pass at all, and hence in later experiments ignition had been effected by fusing platinum wire by means of an electric current. So far as the experiments went there was no very great difference, in the weakest mixture that could be fired, whether the pressure were high or low, although a slightly weaker mixture could be fired at the higher pressure.

Professor Marchant asked whether Professor Thornton had tried varying the self-induction in the circuit when experimenting with "break" ignition, and he would like to know what the actual value of the self-induction was in these experiments, so as to compare the energy with that expended when the spark was due to a condenser discharge.

In reply, Professor Thornton said that on increasing the size of his explosion vessel from 10 cc. to 300 cc. he had found no effect due to the change in the dimensions. He did not think that such a change altered the temperature of the space round the spark in which the ignition originated. In reply to Professor Marchant, the effect of adding inductance would be, he said, to yield a long-drawn-out spark, whilst a condenser gave the shortest possible spark. In his experiments the circuit was practically non-inductive.

The Capacity of Aerials.

The first paper taken on Thursday afternoon was contributed by Professor G. W. O. Howe and dealt with "The Calculation of the Capacity of Aerials, including the Effects of Masts and Buildings." The paper was an extension of papers read at the two preceding meetings of the Association. The exact calculation of the capacity of an ordinary aerial is beyond the reach of mathematics, but Professor Howe has shown that a close approximation can be obtained in the following way. In the first place the effect of the earth on the capacity is represented by an image of the aerial charged oppositely to the real aerial, and situated below it, just as if it were the reflection of the original in a mirror. The whole of each aerial, both the real and the image, is considered as divided up into a number of equal small elements. Each of these is assumed for the purpose of the calculation to be completely insulated, and is given a unit charge of electricity. The potential of each of these elements due to its own charge and to the induction from all the other charges, both real and imaginary, is then calculated. The true potential of the aerial when carrying a charge equal to the sum of all the real charges is then assumed to be the average of the sum of all the elementary potentials calculated as above. Some of the more simple forms of aerial were dealt with in this way in the papers read by Professor Howe at the Sydney and at the Manchester meetings of the British Association, and in the paper read at Newcastle the author applies the method to very complicated types. Some discrepancies apparent when the preliminary results were compared with actual experience were traced to the interference of the masts and other gear by which the aerial is supported, and which it turns out cannot be neglected, as their influence is considerable.

The discussion was opened by Mr. Campbell Swinton, who expressed his appreciation of the admirable way in which the author had in his three successive papers gone on from step to step, from the elementary form discussed at Sydney to such complicated arrangements as were dealt with in the paper read that day.

Professor Marchant, who followed, said that the paper would be of very great value for finding the approximate capacity of aerials, but the speaker was inclined to think that it would be necessary in practice actually to measure the capacity, as it appeared from the paper that a high degree of accuracy could not be expected.

In reply, Professor Howe said that, given all the data, the calculation could be made with an error of not more than 1 or 2 per cent. Indeed in most cases the capacity could be calculated to as high a degree of precision as it was possible to measure it using an ordinary wave meter. In practice, however, an error might arise, since in his paper he considered the charge to be a static one. At high frequencies other matters came in. Thus, for example, a wooden mast acted as a conductor for a static charge, but at high frequencies the charge would have difficulty in getting up and down such a material; so that the effective capacity would vary with the wave length. If the latter were near the fundamental note of the aerial matters were still more complicated. He had assumed in his paper that the aerial was to be used for wave lengths longer than its fundamental.

The Poulsen Arc.

A paper entitled "Some Characteristic Curves of a Poulsen-Arc Generator" was next read by Mr. N. W. McLaclan. In describing the object of his experiments the author stated that Mr. F. Mercer had already shown that with a carbon-copper arc burning in hydrogen, without a magnetic blast, having a condenser (the capacity not exceeding a certain limit) and a variable inductance shunted across its terminals, there is a certain inductance and, therefore, frequency, for which the shunt current is a maximum. His own investigation was (he said) undertaken to determine whether this condition was applicable in the case of a Poulsen-arc generator (1) when energy was absorbed in the shunt circuit by a variable non-inductive resistance, (2) when the energy absorbed in the shunt circuit was as small as possible. In both these cases there was a loss in the Moscicki condensers, this being unavoidable, unless air condensers were used.

The experiments were carried out in the laboratories of Liverpool University and led to the following conclusions:—

1. With fixed capacity and frequency there is a certain resistance giving maximum power absorbed in the shunt circuit. There is also a certain resistance for which the efficiency of the arc is a maximum; but the resistance corresponding to maximum power is smaller than that corresponding to maximum efficiency.*

2. With fixed capacity and fixed resistance in the shunt circuit there is a certain inductance, and therefore frequency, for which the power obtained from oscillations of fundamental frequency is a maximum. For capacities of limited value the total power from oscillations of all frequencies has a maximum value, but for capacities beyond a certain limit there does not appear to be any definite maximum value. The same conclusion applies in connection with the efficiency of the arc, but the resistance corresponding to maximum power is smaller than that corresponding to maximum efficiency.

3. With given resistance and frequency the power obtainable in the shunt circuit (both total power and that due to oscillations of fundamental frequency) and the efficiency of the arc increase with the capacity; but with larger capacities (of the order of 0.00368 mfd. and upwards) the burning, especially with small inductances, is apt to be irregular and noisy, i.e., when the ratio L/C is small.

4. When the power absorbed in the shunt circuit is very small, the capacity being fixed and not exceeding a certain limit, there is a certain inductance, and therefore frequency, for which the shunt current is a maximum. For capacities beyond a certain limit there does not appear to be any definite maximum value.

5. A diminution in the strength of the magnetic blast does not cause any appreciable alteration in the maximum power and maximum efficiency. The maximum power occurs at a lower frequency, and more power is obtainable at lower frequencies than with a stronger blast.

6. A diminution in the strength of the magnetic blast does not cause any appreciable alteration in the fundamental frequency of the oscillations in the shunt circuit: but there is a tendency for the second harmonic to increase with capacities of 0.00368 mfd. and upwards.

7. The most prominent harmonic in the shunt circuit is the second, thereby showing the existence of an asymmetrical current wave. This harmonic for any given capacity increases with decrease in inductance, and, therefore, increase in frequency. For a given frequency the second harmonic increases with the capacity.

8. The insertion of resistance in the shunt circuit causes the burning to be less regular than it is without resist-

* Efficiency based on oscillations of fundamental frequency or total efficiency. Both efficiencies occur with the same resistance.

TURRET LATHE FOR BARS.

CONSTRUCTED BY MESSRS. HAIGH'S (OLDHAM), LTD., ENGINEERS, OLDHAM.

(*For Description, see opposite Page.*)

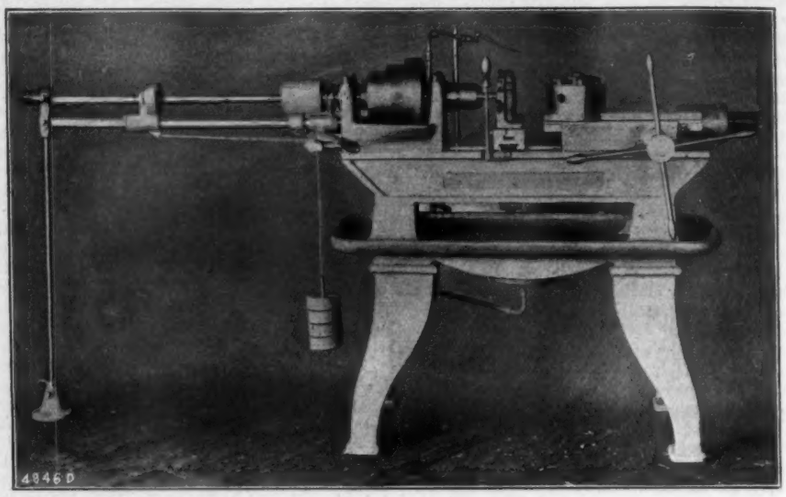


FIG. 1.

MILLING MACHINE.

CONSTRUCTED BY MESSRS. HAIGH'S (OLDHAM), LTD., ENGINEERS, OLDHAM.

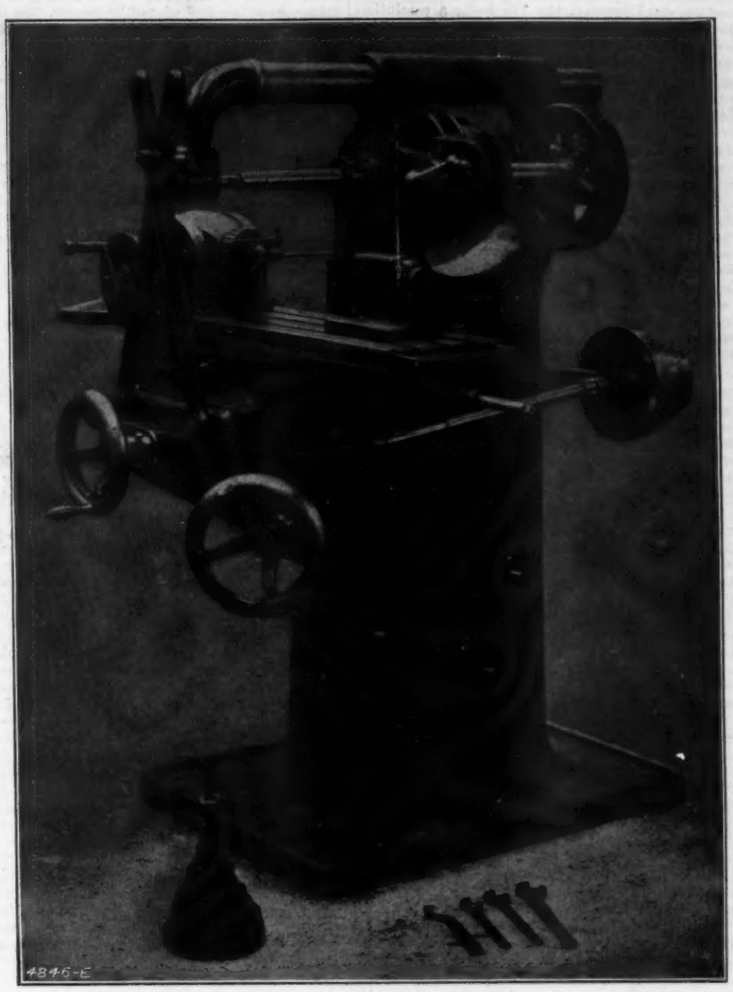


FIG. 2.

ance. The irregularity of the burning increases with increase in the resistance.

The discussion was opened by Professor Marchant, who called attention to the non-inductive resistance employed by the author in his experiments. Resistances which were non-inductive at high frequencies were difficult to obtain, but the sandstone impregnated with copper sulphate used by the author was quite constant and worked well. Mercer, in his experiments, had found two frequencies for which the current was very large, but only one such frequency appeared in the author's experiments. Much difference of opinion had been expressed on the effect of frequency on capacity. Hopkinson had said that with a certain glass used by him the specific inductive capacity increased with the frequency, but in another case he found little change; whilst the speaker himself had found a diminution. Apparently the discrepancies were due to the different kinds of glass used, but it was evident that capacities to be used on wireless work should be measured at the actual frequency to be used.

Mr. Killingworth Hedges asked for details of the non-inductive resistance.

Professor Howe said that he had been most interested in the author's work, since the Poulsen arc had never been investigated quantitatively, and experimenters with it had had little to guide them as to the best conditions. He hoped the author would go further and get at the reasons for the peculiarities observed. Anyone who had used the Poulsen arc would appreciate the labour involved in the experiments. Generally the arc would run well for, say, a quarter of an hour, and then start jumping all over the place, making it necessary to take out and turn up the carbon in the hope that it would then run for another quarter of an hour. The preparation of the paper must have meant weeks and months of hard work.

Mr. McCall asked if altering the inductance in the continuous current used would not affect the secondary circuit.

In reply, the author said that the non-inductive resistance, of which particulars were asked, consisted of a block of sandstone resting on blocks of paraffin in a glass tank. At each extremity of this tank was a large copper plate and the resistance could be varied by altering the distance between these two plates or the amount of sulphate of copper.

COMPLEX STRESS DISTRIBUTION.

The report of the Committee on "Complex Stress Distribution" was next read. It is reprinted on page 268 of this issue. The discussion was opened by Major Morrow, who suggested that the Committee should work up and correlate the large undigested mass of data which had been accumulating for years. For example, much work had been done on the effect of the speed of the alternations of stress in fatigue experiments. In some cases the experiments seemed to show the number of repetitions of stress which could be carried before fracture depended upon the rate of alternation. The matter was a fundamental one, and certainly needed clearing up. Again, anyone who went through our workshops would find structures and machines subjected to stresses which, calculated in the ordinary way, exceeded the elastic limit. In Dr. Stanton's report he noticed that the range of stress in some of the experiments was 50,000 lb. per square inch. This appeared to be somewhere near the ordinary breaking stress, and he would ask if the elastic limit was not exceeded here, although the stress was calculated as if it remained below the elastic limit. Again, in comparing torsional with other experiments the maximum shear was, in all cases, he noted, more than half the principal stress. Such a state of affairs did not give the principal stress theory of resistance (which he did not mean to uphold) a chance.

Mr. C. E. Stromeyer said that in comparing bending with torsion tests he had not himself got a good agreement with the maximum shear theory. Unfortunately, however, he had had in his bending tests to find the fatigue limit by extrapolation, and its position was therefore not nearly so definite as in the torsion tests, where it was determined calorimetrically.

Dr. Stanton said that the large effect of speed of alternation, which had been found in certain of the older tests, appeared to be due to the use of defective apparatus. Certainly for a range of from 20 to 2,500 repetitions per minute there was no speed effect, though there was some when the rate was raised to 5,000 per minute. In reference to Dr. Morrow's criticism, he might say that it was intended to extend the tests so as to include cases in which the shear stress was less than half the principal stress.

Professor Petavel said that if Major Morrow referred back to the earlier publications of the Committee he would see that a fairly complete analysis of all the data obtained up to the date of their appointment had been made, and it was intended to deal in the same way with the data which had accumulated since then.

(To be continued.)

TURRET LATHE FOR BARS AND MILLING MACHINE.

IN the view Fig. 1 on the opposite page we illustrate a turret lathe for 1 in. bars, and in Fig. 2 on the present page a universal milling machine, both built by Messrs. Haigh's (Oldham), Limited, machine tool makers, Oldham. The principal dimensions of the turret lathe are the following :—

Height of centres	6 in.
Diameter of turret	7 in.
Diameter of holes in turret...	1 in.
Traverse of turret, locked ...	4½ in.
Centre of tool holes to top of turret slide	1¼ in.
Largest bar admitted through wire feed	1 in.
Bore of spindle	1¼ in.
Diameter of cone	9, 7½, 6 in.
Width of belt...	2 in.
Distance from nose of chuck to face of turret	12 in.
Swing over cut-off slide ...	5½ in.
Speed of countershaft ...	250 r.p.m.
Spindle speeds	170, 250, 375.
Diameter of fast and loose pulleys	9 in.
Width of fast and loose pulleys	5 in.
Floor space occupied ...	8 ft. 3 in. × 3 ft.
Approximate net weight ...	8 cwt.

The bed is of box section, mounted on a tray and two strong legs, a dish being cast in the centre of the tray to drain the lubricant. The spindle is of high-carbon steel; it revolves in parallel, self-oiling ring bearings of bronze, and carries a large diameter three-speed cone. The nose is screwed to receive the collet-chuck, and the thrust is taken on a ball race. The bar feed is of strong construction and operated by weight, a floor support being provided. The turret slides are strongly proportioned, and are operated by a pilot handle. The turret is round, and arranged for six tools with very efficient clamping bushes. The index plate and plunger are of high-carbon steel and hardened. Six stops are provided, one for each tool, and revolve jointly with the turret, thus ensuring the operation of the correct stop for each tool. The disc carrying the stops is rigid and solid. The cut-off slides are operated by a lever which can be set at any desired angle. Two adjustable tool-holders are

supplied, each tool having an adjustable positive stop. The tool-holders are of the open-side type, and can be set to cut off close up to the nose of the chuck, each having a circular adjustment for elevating the cutting point of the tool without the use of packing pieces. The spindle speeds can be altered to suit the requirements of each particular case.

On page 249 we illustrate a universal milling machine by the same makers. It consists of a strong body casting, with suds tray cast round the base; the body casting carries a strong top arm for supporting the arbor, the driving cone and gearing. The inside forms a cupboard. The headstock is driven by a three-speed cone and back gearing. The spindle is of high-quality steel, revolving in gun-metal conical bearings; it is hollow, to allow a bolt to pass through to secure the mandrel, the latter being supported in the spindle by a morse taper and driven by a cross-slot. A taper collet is provided in the top arm stay to support the outer end of the mandrel. The top table has a large working surface, and has three tee slots for clamping down the work and a suds trough at each end. The table is arranged to swivel over 45 deg. on either side of the spindle. The knee slide is well gibbed to the upright and has a vertical hand adjustment by screw; hand adjustment is provided to all the slides. The table has self-acting motion driven by four-speed feed cones and a telescopic shaft. The feed can be tripped at any desired point by an adjustable trip dog at the front. The knee slide can be clamped to the top arm by a pair of brace stays. All the gears are machine-cut and guarded where necessary. The principal dimensions of the machine are the following:

Self-acting feed of table	...	20 in.
Traverse adjustment of table		8 in.
Vertical adjustment of table		14 in.
Working surface of table	...	2 ft. 4 in. × 8¼ in.
Width of T-slots	...	⅝ in.
Morse taper in spindle	...	No. 3
Diameter of cutter arbor	...	¾ in.
Distance from centre of spindle to top arm	...	5¼ in.
Diameter of cone	...	9, 7 and 5 in.
Width of belt	...	2 in.
Spindle speeds	...	10, 27, 50, 97, 175, 315
Feeds, cuts per inch	...	200, 116, 75, 50, 35, 22, 12
Diameter and width of countershaft pulleys	...	9 in. × 2¾ in.
Speed of countershaft	...	175 r.p.m.
Approximate net weight	...	12 cwt.

The machine can deal with a great variety of work, such as gear cutting, fluting taps and reamers, milling hexagon or spare nuts, spirals, &c. The heads are arranged for hand dividing or geared from the table screw.

Association of Railway Companies' Signal Superintendents and Signal Engineers (England).—The fifty-third conference of this association will be held at the Railway Clearing House, London, on Thursday next, the 21st inst.

The German Potash Syndicate.—According to the report of the Board of this Syndicate, the sale during the first seven months of the present year amounted in value to 103,200,000 marks (5,160,000*l.*), against 70,400,000 marks (3,520,000*l.*) for the same period of the preceding year, the quantity sold during the said period of this year not falling much short of the corresponding quantities for 1913 and 1914. The sale to German agriculturists accounted for about 70,000,000 marks (3,500,000*l.*) out of the above total. The demand for the autumn is very active and can only be met if the shortage of labour be overcome.

Shipbuilding Activity.—We hear that a new shipyard, styled the Hamburger Werft, is about to be started in Hamburg under the auspices and the management of the Hamburg-American Steamship Company, with Herr Ballin as chairman of the Board. The share capital is stated to be only 1,000,000 marks (50,000*l.*), and the new concern is intended to build cargo steamers of a uniform type. The work of the new Stavanger yard, which will be the largest shipbuilding concern in Norway, is being pushed ahead with considerable energy. It is about a year since work commenced, and to make room for four new slips (the yard is an extension of the old Rosenberg Engineering Company) some 36,000 cub. m. (1,300,000 cub. ft.) of rock has already been blasted, 8,000 cub. m. (280,000 cub. ft.) still remaining to be removed. The four slips will be 160 m. (525 ft.) long, capable of accommodating vessels of 14,000 tons. The blasted rock has been used for filling up purposes, quays having to be constructed of a length of 650 m. (2,130 ft.). The shops will in the aggregate cover an area of 5,800 sq. m. (about 60,000 sq. ft.). The blasting operations for the new dock are on a larger scale still, and this work will take about two years. The dock will have a free length of about 565 ft., and will thus be able to take the largest vessels ever likely to arrive in Norway. It will be constructed so as to be able to dock two vessels at the same time. The whole concern will be in full swing in the course of four years. The largest of the present slips will be kept unaltered, whereas the others will be enlarged.

INDUSTRIAL NOTES.

The Trade Union Congress, to which we referred on page 223 *ante*, continued its sittings at Birmingham on Thursday, Friday and Saturday of last week. At the meeting on Thursday, the 7th inst., a resolution was passed instructing the Parliamentary Committee of the Congress to lose no opportunity after the war to press for the repeal of all Acts of Parliament imposing economic, industrial and military compulsion upon the manhood of the nation. The delegates from America, Canada, France and Belgium addressed the Congress and extended to it the greetings of their respective country's workers. A resolution was then passed declaring, as essential to the Trade Union movement; that all men in the Army or Reserve employed in civil industrial pursuits should be absolutely free from military control whilst so employed. A resolution was also carried instructing the Parliamentary Committee to press that the State employment and payment of deputies be included in the Amended Mines Bill, and that any further legislation on the eight-hour day movement shall include in such movements the colliery firemen, examiner and deputy.

At the meeting on Friday, the 8th inst., the Congress considered the employment of Chinese and cheap Asiatic labour in British ships; it resolved to request Government to introduce a Bill to repatriate all Chinese who could not prove their British nationality, and to provide that no Chinese, in future, be signed on British ships west of the Suez Canal. The Labour Exchanges were again submitted to much adverse criticism in regard to the unemployment problem and unemployment insurance. It was resolved, also, owing to the increased cost of living, to urge upon the Government the necessity of fixing maximum prices or of taking full control of supplies.

Most of the business transacted at the last meeting, on Saturday, the 9th inst., was of a political nature and therefore outside the scope of our columns. The following 17 delegates were elected on the Parliamentary Committee for the ensuing year:—H. Gosling (London, Amalgamated Society of Watermen), 2,304,000 votes; J. W. Ogden (Heywood, Amalgamated Weavers), 2,010,000; J. H. Thomas, M.P. (Railwaymen), 1,981,000; R. Smillie (Miners' Federation), 1,939,000; J. Hill (Newcastle, Boilermakers), 1,743,000; J. H. Jenkins (Cardiff, Shipwrights), 1,741,000; J. Sexton (Liverpool, Dockers), 1,680,000; Will Thorne, M.P. (General Workers), 1,574,000; A. Onions (Miners' Federation), 1,488,000; E. Judson (Ashton-under-Lyne, Spinners), 1,179,000; W. Mosses (London, Pattern-makers), 1,148,000; W. J. Davis (Birmingham, Brassworkers), 1,089,000; G. H. Stuart Bunning (London, Postmen's Federation), 1,050,000; R. B. Walker (Fakenham, Agricultural Labourers), 1,016,000; F. Bramley (London, Furnishing Trades), 997,000; E. L. Poulton (Leicester, Boot and Shoe Operatives), 908,000; T. A. Flynn (Manchester, Tailors), 892,000.

It was finally decided to hold next year's meeting of the Congress at Blackpool.

Meetings of the Executive Committee of the National Union of Railwaymen have been held this week in London, to consider the demand for an all-round increase of 10*s.* per week in the wages of railwaymen, to which we referred on page 150 *ante*. On Wednesday last a meeting of representatives of the railway managers and of the men was held at the Midland Grand Hotel, St. Pancras, when the men's demand received a preliminary examination. The meeting resumed on Thursday.

According to the observations of Americans who have been in close touch of late with conditions abroad, says *The Iron Age*, production is being carried forward in Europe with a degree of intensity which formerly only existed in isolated cases. This is true not only in the metal trades but in many other lines, for the needs of armies and navies to-day are extremely diversified, and the wants of the civil population must be cared for with a smaller capacity for producing. This progress toward the adoption of what have been called American methods in machinery manufacture will have to be reckoned with when the war is over. . . . To take the American machine-shop, it has been said repeatedly that the true journeyman mechanic is becoming rarer each year. He has been succeeded by such specialists as the lathe hand, planer hand, finishing-machine hand, and so on. Even were a liberal supply of all-round machinists available to-day, a very large number of them would be distributed among the several groups of machines, each to specialise in one department of the work. . . . The employment of women and inexperienced men in great numbers to replace workmen who have gone to war has made necessary the specialisation of training and employment. . . . On the whole, it is entirely reasonable to expect, under the methods now applied, that the total efficiency of the metal-working industries in the belligerent countries after the war will be greater than it was two years ago, in spite of the war inroads upon the ranks of workers.

The Spanish journal *Revista Minera, Metalurgica y de Ingeniería*, publishes the text of a decree recently placed before the Spanish Parliament for acceptance, according to which the companies or industrial enterprises which, by virtue of a concession granted by the State, have charge of public works, are bound to recognise the associations and unions legally constituted by their men. When a workmen's association legally constituted addresses a petition or a claim to a company, if the latter does not reply, the association is to approach the Government and to state the date at which it approached the company. In this case the Government will place the matter before the company and will act in such a way as to reach a solution and prevent any social conflicts. Should relations be broken off between a company and a workmen's association, the company or the association will approach the Government. Should the Government not succeed in bringing the two parties to an agreement, the matter is to be put before the Instituto de Reformas Sociales, and upon the report of the latter Institution the Government will decide the case as it deems best in the public interest.

Our contemporary reproduces the remarks made by the journal *El Economista* in regard to the decree in question. The latter journal says that in future no capitalist will be found so mad as to compromise his funds in enterprises similar to those covered by the decree.

A recent Act regulating the working of factories in India extends to all factories employing 50 persons or more in any part of the year; and by order of any provincial government it may be extended to factories employing 20 persons or more. The Act became operative throughout India in 1914, and commendable efforts were made by all concerned to ameliorate the conditions of factory life, the staff of factory inspectors receiving the active co-operation of mill managers and agents. The staff of factory inspectors has recently been 14. The total number of factories returned as registered under the Act in 1914 was 2,936; these included factories belonging to the State and local bodies. The average number of persons employed daily was 951,000, including 144,000 women and 60,000 children. The number of accidents reported in 1914 was 4,929, but most of these were not serious, and many of them were not due to contact with machinery. There were 162 convictions for breaches of the Act, of which 56 occurred in the Central Provinces and Behar, 24 in Bombay, and 30 in the Punjaub. The offences were principally the irregular employment of women and children, and failure to send in the prescribed returns, &c.

Mr. Robert Young has been appointed general secretary of the Amalgamated Society of Engineers by 18,441 votes, against 14,245 given to Mr. Tom Mann. Mr. W. Glennie has been appointed assistant general secretary, and Mr. W. Kelly second assistant general secretary.

Mansion House Engineering Meeting.—In view of the national prominence of the engineering industry, the Lord Mayor is convening a public meeting at the Mansion House, at 3 p.m. on Wednesday, the 20th inst., to discuss future trade policy with special reference to the economic utilisation of the engineering works of the nation, which have been so largely expanded in capacity and equipment during the past two years. The organisation of the meeting is being undertaken by the British Electrical and Allied Manufacturers' Association, with the support of the British Engineers' Association, the British Empire Producers' Organisation, and the Engineering and Electrical Sections of the London Chamber of Commerce. Applications for tickets of admission should be sent to Mr. T. C. Elder, Organising Secretary for the meeting, B.E.A.M.A. Offices, 36, Kingsway, London, W.C., or to the secretaries of any of the organisations named.

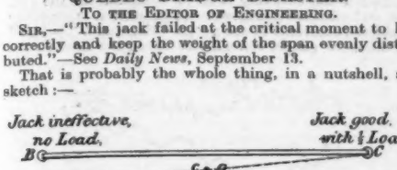
King's Cadetships in the Navy.—Successful candidates for entry in the Navy who are the sons of officers of the Royal Navy, Royal Marines or Army who have been killed in action or have died of wounds received in action, whether afloat or ashore, or have died through the destruction of their ship, or have been drowned or have suffered other violent death due directly and wholly to war service, or have died of disease attributable to active service, may be appointed as King's Cadets. King's Cadets will be entitled to the following privileges in cases where the Admiralty are of opinion that substantial help is needed towards the expenses of naval training:—(1) The grant of an outfit allowance of 40*l.* on first entry. (2) The remission of fees at Osborne and Dartmouth. (3) The remission of private allowance and tuition allowance. In cases where the above conditions are fulfilled by cadets, midshipmen or acting sub-lieutenants already in the Service, the Admiralty may, at their discretion, authorise the remission of all future payments in respect of training fees, private allowance and tuition allowance. King's Cadets will be eligible for compassionate allowances as prescribed by the Regulations, but will not receive the educational allowance authorised by the Order in Council of February 29, 1916.

QUEBEC BRIDGE DISASTER.

TO THE EDITOR OF ENGINEERING.

SIR,—"This jack failed at the critical moment to lift correctly and keep the weight of the span evenly distributed."—See *Daily News*, September 13.

That is probably the whole thing, in a nutshell, see sketch :—



The span was probably carried as from A to C, with grievous twisting effects, and ultimate collapse.

Perhaps it is early yet to speculate on such meagre information as that contained in the cablegram, and no great importance is to be attached to my suggestion till something more is known of the facts.

Yours truly,
W. H. THORPE.

60, Winsham-grove, Clapham Common, S.W.,
September 13, 1916.

[We have dealt on page 259 with the causes of the disaster to this bridge, as far as it is possible to do so by aid of such information as has come over by cable, or had already been published in this country. We hope shortly to receive full particulars direct from America.—ED. E.]

DRAUGHTSMEN.

TO THE EDITOR OF ENGINEERING.

SIR,—The correspondence now appearing in your columns under this heading is serving a good purpose, and I trust I may be permitted to again take part therein and to express the hope that you will permit it to continue while there is anything useful or enlightening to be said on the subject.

The "highfalutin" sentiments so ably expressed by "Chief Draughtsman" are admirable—very; but it does not appear to have occurred to anyone to claim that the employers are "good sorts." To have "cricket," both sides must "play the game," and when one finds some conscientious self-denying draughtsman being put off with an uncertain holiday of one week, and others being singled out and rewarded for conspicuous merit by getting none at all, one wonders wherein the letter from the Draughtsman's Association can be objectionable. That body deserves our thanks for getting an authorised pronouncement on a point of law, and it does not yet appear to be common knowledge that there are "good sports" among the employers in "controlled" establishments who neither give the holiday nor pay the rates considered by Parliament as being just and reasonable for those employed in the country's service.

Tradesmen cover their holiday blank by insisting on a higher rate per working week. Draughtsmen (who are allowed to become such in recognition of ability and merit) balance their holiday pay by reducing their rate per working week and by working overtime free of charge, and employers are not unknown who make the draughtsman's position more definite by refusing sundry recognised allowances and exacting hours that swallow up some of those holidays.

Some weeks ago the address of a "good sort" among the employers was asked for, but probably he, like his champion, has disappeared, as the address is still "unknown." Yes, draughtsmen are, many of them, "good sorts"; therefore let justice be done even if the Draughtsman's Association must be employed to obtain it. The Association is a necessity forced upon us by the associated employers.

Yours truly,
"CLYDESIDE."

TO THE EDITOR OF ENGINEERING.

SIR,—If "Chief Draughtsman" holds the position he ascribes to himself by his nom-de-plume, he betrays a little ignorance of the true position of many draughtsmen. He talks of the draughtsman going "off for his fortnight's well-paid holiday, leaving the workman toiling at the bench," but I beg to state that if he conceded this to the men under his charge he gave more than the majority of draughtsmen got, and also more than a patriotic man (of whom we heard so much in his previous letter) was expected to give or *take* at the present critical moment.

If draughtsmen had all been treated as he makes out I should be inclined to use even stronger language than his to denounce their asking time and a quarter for any holiday whatever.

For "Chief Draughtsman's" edification, I may state that a great number of draughtsmen are on the same terms as the ordinary workman, although they are nominally considered *on the staff*, i.e., should they be off work they receive no pay, and if they are on *holiday*, which for them is only a misnomer, they again receive no pay. Now I think "Chief Draughtsman" will agree with me that draughtsmen on this footing were entitled to as much consideration as the workmen, and if I mistake not it was on behalf of a number of such draughtsmen that the Association approached the Ministry. I may state also that a number of draughtsmen under the same *holiday* conditions had their rooms taken at the coast and had to be content to pay up and look pleasant without getting the use of them—and this without any time-and-a-quarter or any other allowance from the employers.

I am afraid if "Chief Draughtsman" had had *his* rooms taken for his holidays and had to pay for them without getting the use of them, and later on got his holidays minus any pay, he would also have thought it only just and fair that a slight allowance might have been given to him for all his sacrifice, seeing the workmen on similar working conditions were getting so much, and that without, in the great majority of cases, any sacrifice whatever.

The foregoing were the conditions of several draughtsmen I know personally, so that there is little wonder they thought they were hard hit and entitled to some little consideration.

The other points of "Chief Draughtsman's" letter on which he was tackled have been quite diplomatically ignored by him, so I take it that he has been quite satisfied with the answers given, and I trust this remaining drowning man's straw of the time-and-quarter will also have been satisfactorily shown to him.

Apologising for again trespassing on your valuable space.

"A MEMBER."

TO THE EDITOR OF ENGINEERING.

SIR,—"Chief Draughtsman," in his reply to previous correspondence, mainly concerns himself with the Government award of time-and-a-quarter for working on holidays.

This award is unquestionably in respect of a *postponed* holiday; and, in citing the hypothetical case of a draughtsman first enjoying a fortnight's fully-paid holiday, and then coming back and claiming time and a quarter for working on a Bank holiday, your correspondent has conjured up a set of circumstances in respect of which the Government statement makes no such award. As a point of lesser importance he refers to one of the previous correspondent's "darkly hinting" at what will happen after the war.

I have carefully scanned the previous correspondence, but am unable to find any trace of a "dark hint."

I myself said that the *danger* of the restoration of trade union restrictions, coupled with the fact that, in law, the term "workman" now includes "draughtsman," has led to a large influx to the Association. For this reason I suggested that "Chief Draughtsman" should become a member, and I venture to say that his latest letter only serves to make the suggestion the more reasonable.

Yours faithfully,
September 11, 1916. "ABIMELECH."

TO THE EDITOR OF ENGINEERING.

SIR,—Your correspondent, "Chief Draughtsman" seems to me to be a bit inconsistent, for he sets out to make comparison between draughtsmen and workmen, to the detriment of the former and uplifting of the latter, for his patriotism. Then in the third paragraph he talks about the copying of workmen's ways as being degrading. That is my interpretation of his letter.

I agree with "Chief Draughtsman," that draughtsmen have always considered themselves a cut above the rank and file, and this is just the point that has apparently been lost sight of by employers in recent years. Does he agree with me when I say that the draughtsman, compared with the man in the shop, has lost the status he had, say 10 or more years ago?

I feel that draughtsmen have "gone back" very much, in the employer's eyes, and financially, when compared with the workman of to-day, and, mark you, he has to be a much more capable man (and especially capable of accepting a small salary) than in former years. For proofs of this, see advertisements in ENGINEERING, and other technical journals.

If, as "C. D." says, draughtsmen have had their fortnight's holiday, and then came back and claimed time and quarter, then I am with him in his condemnation (and I believe the A.E.S.D. would be with him also) of such conduct.

But, on the other hand, what of those draughtsmen who have had no holiday, no time and quarter, and no war bonus, not even an increase in salary since the commencement of hostilities?

In most cases draughtsmen receive their salary for their fortnight's holiday—and note that this is part of their income—and should these men not receive their holiday, then the employer is pocketing a fortnight's salary *which belongs* to the draughtsman, and what draughtsman at the present time can afford to make that sacrifice? If the employer handed over the fortnight's salary in lieu of holidays, then all would be square and everybody happy. But was this done?

Again, there are draughtsmen who are paid for overtime, but do not have remuneration for lost time, such as sickness, holidays, &c. What has "C. D." to say of these fellows?

In speaking of the high cost of living, "C. D." is evidently not paying much attention to the shipping companies' dividends (possibly he is interested). These people, in my humble opinion, are contributing largely to putting up the prices. When the A.E.S.D. goes the length of compelling a man to do its bidding (against the man's better judgment) then I, for one, will cease to be a member. This is not an association of draughtsmen of the "Dick Turpin" type, and it has no paid agitators.

Finally, if "C. D." is the fair-minded man he would have us believe he is, surely he would not object to read what is the purpose of the Association and why such a thing should exist. I should be interested to hear his opinion after he has perused the Association's literature. I may be wrong, but I cannot help thinking that "C. D.'s" motto must be "If I am all right, then 'nuff said."

Again thanking you for your continued consideration and attention.

I am, yours faithfully,
A MEMBER OF THE A.E.S.D.

SHIPBUILDING IN ROUMANIA.—It is stated that a company has been formed in Bucarest with a capital of 5,000 000 Lei (200,000*l.*) for shipbuilding. The yard is to be on the Danube; in the first instance it will undertake the building of tug boats and lighters, later it may also build sea-going vessels.

ROYAL ENGINEERS—INTERNAL COMBUSTION ENGINES.—Men with a knowledge of internal combustion engines, or of any branch of electrical engineering, are urgently required for the Corps of Royal Engineers, Territorial Force. Age 41 to 47. Personal application should be made to the Chief Recruiting Staff Officer, Great Scotland Yard, Whitehall, S.W., where all further particulars can be obtained.

A NEW IRISH INDUSTRY.—A large factory will shortly be opened in Dublin for the manufacture of electric dry cells and batteries of all kinds, for pocket lamps, telephones, household bells, automobile, and other uses. This factory will give employment to over 200 hands, mostly girl labour. During the war special attention has been drawn to the manufacture of electric dry batteries for pocket lamps. In the United Kingdom the yearly consumption before the war was over 60,000,000 batteries, of which only 8,000,000 were made in England. Germany supplied over 40,000,000.

OUR LOCOMOTIVE EXPORTS.—The value of the locomotives exported from the United Kingdom in August was 99,187*l.*, as compared with 297,326*l.* in August, 1915, and 210,260*l.* in August, 1914. Argentina figured in these amounts for 15,560*l.*, 44,467*l.* and 9,092*l.* respectively. The colonial demand was weak in August, exports being almost at an end to South Africa, while they were greatly reduced to India and Australia. The value of the locomotives exported from the United Kingdom in the eight months ended August 31 amounted to 826,687*l.*, as compared with 1,788,221*l.* in the first eight months of 1915, and 2,641,584*l.* in the first eight months of 1914.

THE MINISTRY OF MUNITIONS.—We are officially informed that the following changes have recently taken place in the office organisation of the Ministry of Munitions:—Sir Glynn West will in future be directly responsible to the Minister for the conduct of his Department, which deals with the manufacture of shells and their components. His title will be controller of shell manufacture. Mr. H. Fowler will accordingly be designated Deputy Controller. The branches dealing, respectively, with the supply of metals, coal, and other materials, and with machine tools, will work immediately under the Director-General of Munitions Supply. Mr. Leonard Llewelyn and Mr. Alfred Herbert thus become Deputy Directors-General. Mr. John Hunter has become responsible for the branch which deals with the production of steel.

IRON, STEEL AND COAL IN GERMANY.—The quantity despatched by the German Steel Union during the month of July amounted in the aggregate to 282,875 tons, against 298,753 tons for the preceding month, 258,092 tons for July, 1915, and 470,000 tons for July, 1914. The goods despatched during July comprised :—

Half-finished goods	...	...	69,386 tons.
Railway material	...	...	130,465 ,,
Sections ...	...	...	83,024 ,,

The production of pig-iron within the German customs union during July amounted to an aggregate of 1,134,306 tons, against 1,081,507 tons for June, 1,047,503 tons for July, 1915, and 1,564,345 tons for July, 1914. Apart from the military requirements, there is an active demand for boiler tubes, and there is also a satisfactory demand for pipes for boring purposes and irrigation undertakings; the works making these are fully employed for the next four or five months. Owing to the rise in the price of raw material and other items, prices have increased, and must now be looked upon as very remunerative. A further rise for some time to come is not contemplated, and the prices fixed in July may in the meantime be considered as maximum prices. The Pipe union agreement runs to the end of the present year and will probably then be extended for six months longer. Whilst negotiations in regard to the renewal of the Rhenish-Westphalian Coal Syndicate are still pending, a number of members have applied to the committee for an alteration in the matter of extra allowance on prices. The production of the coal syndicate during the month of July amounted to an aggregate of 8,161,726 tons. The production of coke amounted to 2,331,541 tons. The demand continues active, but there appears to have been a difficulty in obtaining sufficient rolling-stock. Traffic on the Rhine–Weser and Dortmund–Ems Canal continues to increase, and amounted in July to 437,395 tons. As a proof of the attention paid to lignite deposits in Germany may be quoted the sale of some shares in the Beissel mine at about five times the value at which they stood in 1902, although the mine in question has by no means proved a particularly remunerative investment so far, but the deposits are understood to be very extensive.

LIMIT GAUGES.*

By R. T. GLAZEBROOK, C.B., M.A., D.Sc., F.R.S.

(*Concluded from page 238.*)

TURNING now to the question of providing limit gauges for such threads, we are met with many difficulties. The committee, after a discussion of these, summarised their recommendations thus :—

For Bolts.	*For Nuts.*
1. "Go" and "not go" gauge of the "Taylor" type for pitch and effective diameter.	1. "Go" standard bolt, correct in all particulars, and made to the minimum diameters allowable.
2. "Go" and "not go" double gap gauge for full diameter.	2. "Not go" single thread gauge for full diameter.
3. "Go" and "not go" double gap gauge for core diameter.	3. "Not go" single thread gauge for effective diameter.
	4. "Not go" cylindrical gauge for core diameter.

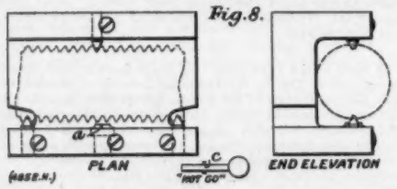


Fig. 8.

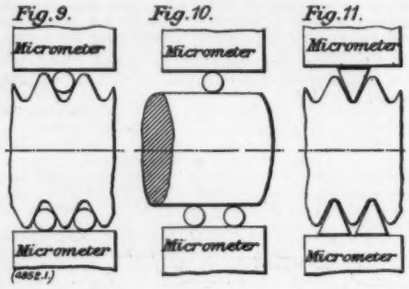


Fig. 9. *Fig. 10.* *Fig. 11.*

The three conical points, accurately ground to an angle of 55 deg., and truncated so as to clear the root of the thread, are distributed as follows :—(i.) Two are fixed on the lower jaw of the gauge, so that the distance between them is an exact number of threads representing twice the length of screw contained in a standard nut of corresponding diameter. (ii.) The third is fixed on the upper jaw midway between the two points on the lower jaw, and the three points are set to a standard male gauge having correct pitch and the maximum effective diameter allowed. Opposite the single point is fixed the flat face *a*, which is adjusted so that the small cylinder *c* (of such a diameter that it will touch the thread about half-way down its depth) will just enter the thread of a bolt made to the minimum effective diameter allowed.

Then in testing, if the bolt enters the gauge, and the "not go" cylinder refuses to enter the thread, the bolt is within the limits for pitch and effective diameter laid down in the tables, while any error in pitch which may be present will be duly compensated by a reduction in the effective diameter.

With this gauge a "go" and "not go" ring gauge is used for the full diameter, and a "go" and "not go" snap gauge for the core diameter. With a complete ring gauge for the "go" gauge, "not go" gauges are required if the checking is to be complete for the full, core, and effective diameters. In practice it is generally considered sufficient to use a "go" ring and a "not go" full diameter gauge, though this opens the door to the employment of thin threads. It should be remarked here that a "not go" screw ring is a useless and misleading gauge; it is difficult and costly to construct; it may tell you, no doubt, that the screw is wrong and ought to be rejected, but it affords no information as to what element in its form causes the rejection.

Up to the present no firm has undertaken the manufacture of the three-point pitch and effective diameter gauges, and they have not come into general use; they suffer also from the disadvantage that the wear is taken on the points, and even if these are properly hardened the life cannot be long.

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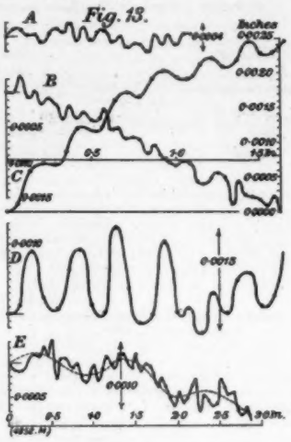


Fig. 13.

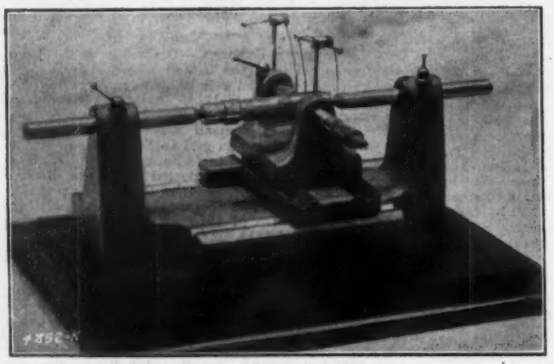


FIG. 12.

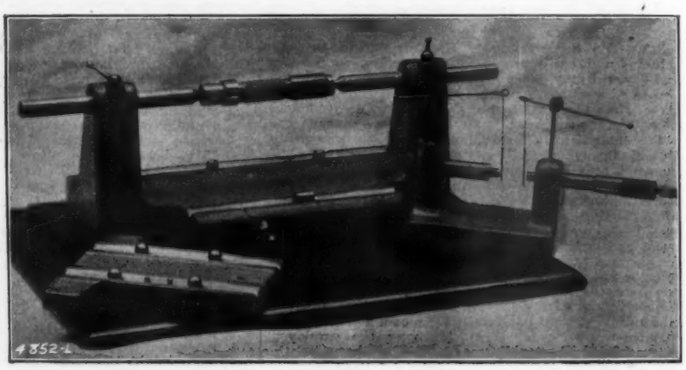


FIG. 12A.

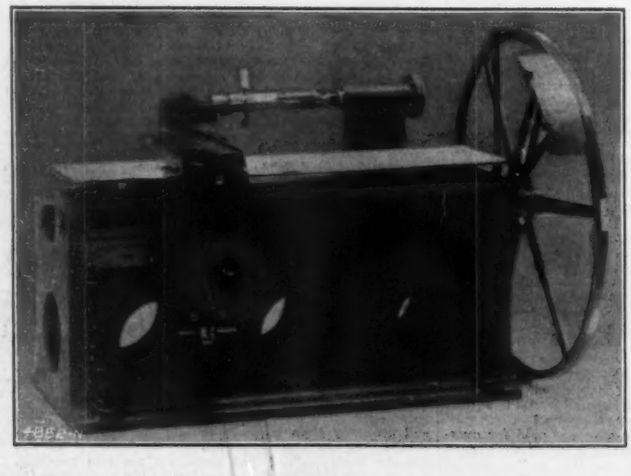


FIG. 14.

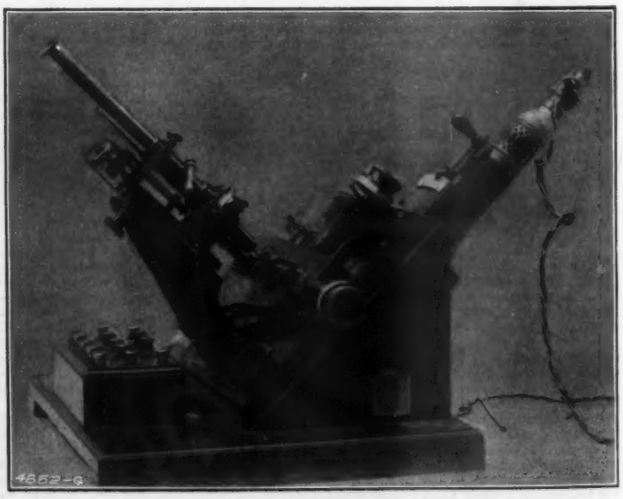


FIG. 16.

* Paper read before Section G of the British Association at Newcastle, September 6, 1916.

† The committee and the engineering industry owe much to Mr. W. Taylor, of Messrs. Taylor, Taylor and Hobson, for his work in this connection.

It is easier to gauge a hole, for in this case the gauges are plugs. A complete plug gauge is required as a "go" gauge, and, to be strict, three "not go" gauges for the core, full and effective diameters. For the core the "not go" gauge is a simple plain plug of appropriate size. For the full and effective diameters we use two screw gauges, each having a single turn of the thread; the first has a very thin deep thread, cut away on the slopes and at the root so as to bear only on its crest, while the second is cut away at the crest and root and bears on the slopes; the diameters are in each case of appropriate size, and the screw is rejected if either gauge enters appreciably. If a "not go" core diameter gauge only is used, holes with thin threads, in which the effective diameter and probably the full diameters are too large, will be accepted.

We pass next to the tolerances on the gauges and the means of checking these; the last is closely connected with the methods of production and has recently been discussed in a Memorandum, "Notes on Screw Gauges,"* issued in February, 1916, from the National Physical Laboratory. In the case of a plug gauge, if a satisfactory ring check is available, the first step will normally be to try it with this. If it fails to enter it is usually rejected, but further examination is made to see to what particular the failure is due. If it enters examination is still necessary to determine whether it is up to size in all its elements; it may have an excessive pitch error which is compensated for by a large reduction in its effective diameter, and in this case it is useless as a gauge. Thus in nearly all cases measurement is required.

For the full diameter a micrometer or some simple form of measuring machine is all that is needed. The principle involved in the measurement of the effective and core diameters is shown in Figs. 9, 10, 11.

For the effective diameter, three small circular cylinders—three carefully selected needles of known diameter—are inserted, as shown in the thread, and a micrometer reading is taken over these; the mean diameter of the needles is determined by measuring them when suspended against a cylinder of known dimensions, and from these two readings the effective diameter can be calculated.

Instead of a plain cylinder we may employ a cylinder having a circular V groove, with an angle of 55 deg. cut in it to a suitable depth. This is tested by means of two accurate cylinders, and its effective diameter is found as though it were part of a screw thread; the method of using it as a reference bar is obvious.

For the core diameter, the circular needles are replaced by three bars of triangular section, the angle at the apex being considerably less than that of the screw; measurements are taken with the micrometer—(1) with the bars against a cylinder of known diameter; (2) with the bars in the thread, and the core diameter is thus found.

To carry out these measurements rapidly at the Laboratory, an instrument is employed as shown in Figs. 12 and 12A.

The screw to be measured is held between suitable centres. A light carriage supporting two micrometers can move on balls either parallel to or at right angles to the axis of the screw; the axes of the micrometers are in the same plane as and at right angles to that of the screw. To measure the full diameter a standard screw is placed between the centres, and one micrometer A is set to some convenient mark; the other B is then adjusted until the standard screw is just held between the micrometers; the pressure required for this should be very light, as the screw is easily deformed. Micrometer A is then withdrawn, the standard screw removed, and the screw to be examined put in place. This screw is then measured, using micrometer A. The difference in readings of A then gives directly the error in the full diameter of the screw. The diameters of most of the screw gauges tested at the Laboratory are thus measured.

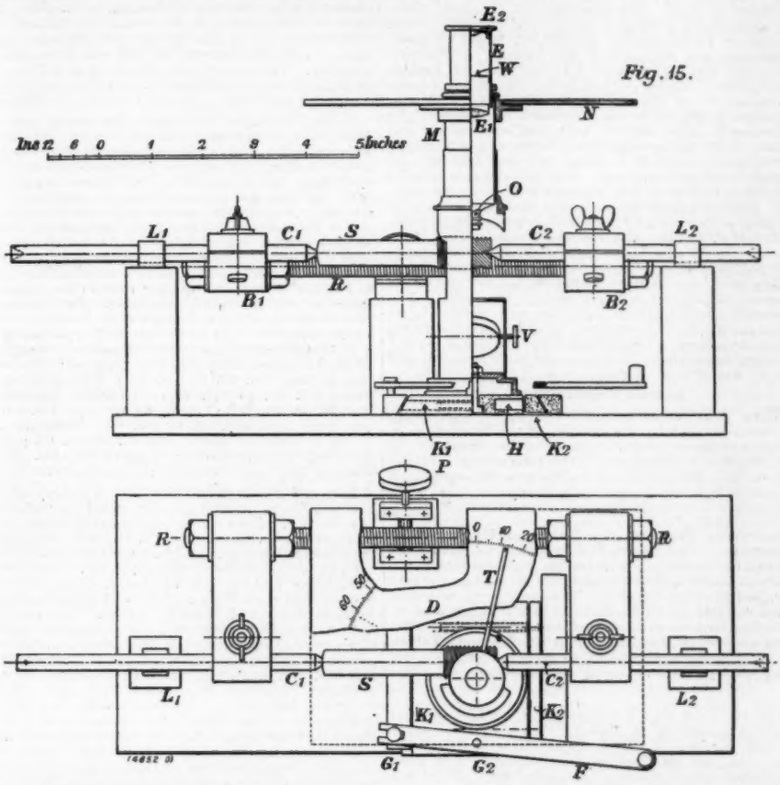
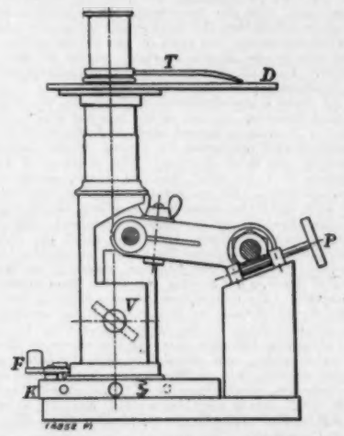


Fig. 15.



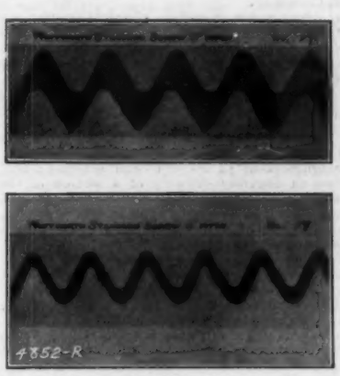


FIG. 17.

Fig. 18. TYPICAL PROFILE GAUGE N°1.

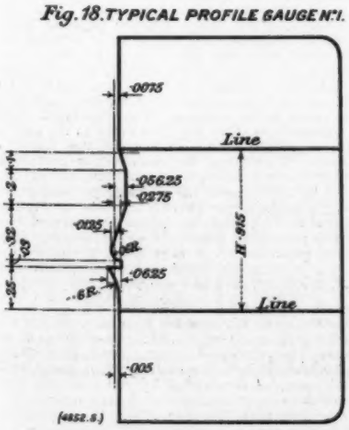
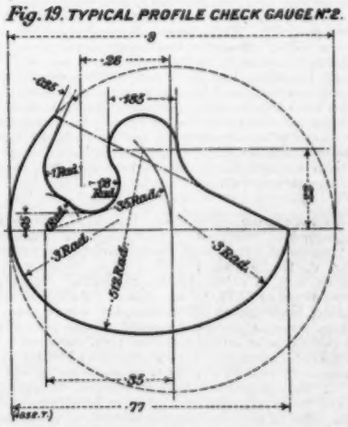


Fig. 19. TYPICAL PROFILE CHECK GAUGE N°2.



Turning now to the measurement of pitch, we notice first that pitch error may be of two kinds:—(a) A progressive error, increasing regularly as we go along the screw; and (b) superposed in many cases on this a periodic error, depending frequently on some want of adjustment in the leading screw of the lathe on which the thread was cut. Examples of these errors will be given later. In measuring the pitch of a screw, it is mounted on centres on a stiff bed which carries a saddle sliding parallel to the line of centres. This saddle is moved by a screw which has been carefully calibrated, and the motion is read on a large micrometer head. In its simplest form the saddle carries a pointer accurately ground to an angle of 55 deg., with its axis at right angles to that of the screw. The pointer can slide in the direction of its own length on the saddle. The pointer is set by the micrometer with its two edges in contact with the sides of a thread and a reading taken. It is then withdrawn, the micrometer is turned until the pointer is opposite the next thread, when it is again adjusted, and so on. A series of readings taken thus give the distances between the consecutive roots of the thread, *i.e.*, the pitch, and from these the pitch error is calculated. The method is clearly slow and not very accurate; it is difficult to set the pointer. The method in use at the Laboratory is as follows:—

The screw is mounted as before, but the feeler carried by the saddle takes the form of a small spherical ball at the end of a bent lever. The ball is held pressed into the threads of the screw by a light spring, and as the saddle is traversed along the ball moves to and fro, always remaining in contact with the screw. The ball is too large in diameter to reach the bottom of the thread. In its motion it slides down one flank of the thread until it is arrested by contact with the opposite flank, when it immediately begins to move up this flank; this change of motion is very sharply defined. By noting on the micrometer screw the positions of the slider at which these changes of motion take place, we clearly have a means of measuring the pitch of the screw. To effect this a mirror is attached to the arm carrying the small sphere and rotates backwards and

* To be obtained from Mr. W. F. Parrott, The Causeway, Teddington, or through the Engineering Standards Committee.

forwards as the arm moves. A spot of light reflected from the mirror on to a scale moves in one direction, then stops and moves back; after a time its motion is again reversed, and so on. The sharp reversals caused by the point of contact of the sphere passing from one flank of the screw to the opposite flank are clearly defined, and by their means an accurate measure of the pitch is obtained. Fig. 13 gives some curves actually obtained at the Laboratory in this way, while the instrument itself is shown in Fig. 14.

To measure the angle and form of a thread, a microscope is most conveniently used. The microscope is fitted with cross wires and can rotate about its axis. Some means of measuring this rotation is required. Means also for bringing the part of the screw to be examined, and for focussing, are required, and care must be taken that the light which enters the microscope may come along the rake of the thread. The axis of the microscope is set at right angles to that of the screw. Fig. 15 shows a simple apparatus devised at the Laboratory for this measurement.

To make a measurement of the angle, the microscope is first focussed on one of the centres which carry the screw; it is then moved aside and the screw is put in position and traversed by means of the adjustments until in the field of view. This method of focussing ensures that an axial section of the screw is under examination. The microscope is then rotated about its axis until the cross wire is along the flank of one of the threads and a reading is taken; the tube is turned and the screw traversed until the cross wire lies along the opposite flank, and a reading is again taken; the difference between these gives the angle of the screw. By setting the cross wire to run along the crests of the thread and taking a reading, the squareness of the threads to the axis can be verified, while the general shape of the thread is obvious to the eye. By attaching the part carrying the screw to two slides at right angles, one parallel to and the other at right angles to the axis of the screws, fitted with accurate micrometers, measurements of the diameters and pitch of a small screw may be made. Fig. 16 shows such an instrument made by the Cambridge Scientific Instrument Company.

In many cases, however, observations on angle and form can be made most readily by a projection apparatus. The screw is suitably mounted and illuminated by the aid of a small arc lamp and condenser. Carefully arranged lenses throw a magnified image on a screen, and observations are made on this image. The lenses must be chosen to produce uniform magnification over the field and there must be absence of distortion. At the Laboratory lenses to secure this have been obtained, and the method has proved rapid and of great value. A magnification of 50 has been selected; the screen carries an accurate drawing of a section of the screw 50 times actual size. It is easy to compare the image formed with this correct profile. The screen carries adjustments which serve to bring the image and the drawing readily into coincidence.

Another method of comparison is to project simultaneously the image of an accurate screw placed alongside the one under examination; the differences are readily apparent. Fig. 17 gives some photographs of screw gauge threads sent for examination taken in this manner contrasted with the standard form.

The checking of screwed ring gauges is more difficult. Direct measurement is only possible if they are of considerable diameter. Means have been devised, provided the ring is not too small, and, where the information is specially required, are employed for measuring the diameters by the aid of small spheres, fitting into the threads, and internal micrometers. In general, however, check gauges are resorted to, the Taylor system being employed whenever real accuracy is desired. This in itself does not give a measurement of the diameter, but it is generally possible by the use of a sufficient number of checks of slightly different sizes to form a close estimate of the limits within which it lies. A simple and rapid method of measuring internal diameters, especially of small screws, is much to be desired.

III. *Form and Position Gauges.*—These, which are often extremely difficult to make, to measure and to check, perhaps hardly come within the category of limit gauges. In the case of plate form gauges, the examination can sometimes be done readily by measurement, but check gauges are usually necessary, and the observation is made by bringing the two into contact on a plate of glass and holding them up to the light. The eye can readily detect a want of fit; to say exactly what is wrong is more difficult, *e.g.*, in the case of an elaborate band gauge for a shell. We have found the difficulty best met by the supply to the maker of an accurate check in addition to the drawing. More recently the projection apparatus employed for checking the form of a screw thread has been freely used and has given good results. Figs. 18 and 19 show some examples.

Position gauges, again, need checks for their verification, and the design and manufacture of these often present difficulties. The check is clearly an accurate replica of the part which it is intended to gauge, made, however, in a form which lends itself to exact measurement so that its accuracy may be secured. The details of measurement will differ for each gauge and no general account can be given.

Limit gauging is a wide field to discuss, and in this hasty survey the fringe has only been touched. The experience of the past year has shown its importance, and when once this was realised and the fact that accuracy was essential was grasped, British manufacturers have risen to the occasion and may be proud of the output of beautiful gauges now being passed into munition works.

NOTES FROM THE UNITED STATES.

PHILADELPHIA, August 30.

General steel conditions remain the same. Pig-iron has again been in great demand, especially for steel. Lots ranging from 5,000 to 40,000 tons have been taken for delivery next year, mostly at an advance of 50 cents. All large consumers are becoming anxious. Business is pending for 200,000 tons, one-fourth for Canada. Italy wants a large supply. High ocean freight rates are checking sales. It is believed a large buying movement has set in. After the recent rush of munition orders temporary quiet prevails, though numerous inquiries are before the market. The mills are largely sold up to July, 1917. For this reason new business will not be expected soon. Domestic demand is again active for agricultural steel and bridge and building work. England is in the market for 100,000 boxes tin-plate, presumably for shipment to the Orient. A Pennsylvania mill sold 15,000 tons 6-in. channels for France. The reported contract at Chicago for 170,000 tons rounds for export is not denied. Recent European shell contracts are estimated to cover 3,000,000 large shells. To these may be added 500,000 tons shell steel within two weeks. Italy has arranged for 12,000 tons ship-plates. All shipyards are after plates and the aggregate of pending inquiries is very large. The Pennsylvania railroad has arranged for 15,000 tons plates and shapes for car work. Very large inquiries for structural steel are coming in, denoting a very marked revival of large building operations. J. P. Morgan will close this week for somewhere between 50,000 and 75,000 tons of structural shapes in short lengths, which is suggestive of contemplated use in trench work somewhere. Other structural orders of moment, for export, will go through this week. The pressure for mill products from domestic sources is increasing, but the oversold mill conditions are restrictive of actual business. The outlook is hard to define beyond the very patent fact that demands both domestic and foreign are beyond capacity.

ELGAR SCHOLARSHIP, 1916.—The Elgar Scholarship has been awarded by the Council of the Institution of Naval Architects to Mr. Reginald John Shepherd, of H.M. Dockyard, Devonport. The scholarship is of the value of 100*l.* per annum, and, subject to the regulations governing the same, is tenable for three years.

PROJECTED ELECTRIC ORE-SMELTING UNDERTAKING IN SWEDEN.—The Lafors Fall is stated to have been sold to a syndicate, in which foreign capital is interested, for about 55,000*l.*, the Swedish State having had the first offer, but having refused it. The energy will be transmitted *via* Ramsjö to Sundsvall, where it is intended to be used at large electric ore-smelting works to be erected there, and where the power from the Rågunda Fall in the Indal River is also likely to be employed, the two falls probably being exploited simultaneously.

HAWAII.—Last year witnessed great agricultural and industrial prosperity in Hawaii. The output of sugar was 640,000 tons, of the estimated value of 60,000,000 dols.; this was marketed at San Francisco, New York and Philadelphia. Canned pineapples were turned out to the extent of 2,300,000 cases, and there was a large output of rice, while the banana industry showed general progress. There were, also, increased shipments of Koan coffee. Some of the sugar plantations yielded dividends last year of 12, 14, and even 16 per cent. The Panama Canal has had the effect of increasing Hawaiian shipping business, and the authorities of Honolulu have lost no time in providing increased facilities, a floating dry dock for merchant vessels having been introduced. New wharves have been built and opened, the harbour has been deepened, and the Federal breakwater at Hilo has been extended. American influence has thus far certainly worked well.

INDIAN FORESTS.—The State forests of British India are classified as "reserved," "protected," or "unclassed." The "reserved," including leased forests, in which the control of the Forest Department is most complete, cover an area of about 96,300 sq. miles. Outside the reserves there are 141,000 sq. miles of unclassed forests, including large tracts of unoccupied waste land, and 8,400 sq. miles of protected forests. Some part of these will eventually be brought within the "reserved" area, especially in Assam and Burma, in which the forest area represents 46 and 63 per cent. respectively of the total area of the province. Forest revenue is raised by royalties or by the sale of timber or other produce and by the issue of permits to graze cattle, or to extract for sale timber, firewood, charcoal, bamboos, canes and minor forest products. The gross revenue derived from forests in 1914–15 was 1,980,652*l.*, including 351,309*l.* and 1,497,377*l.* received for timber and other produce removed from the forests by Government agency and consumers respectively. The charges amounted to 1,217,808*l.*, leaving a net revenue of 762,844*l.* In the United Provinces the settlement of the Kumaon Circle was continued. Last year the production of timber was 8,700,000 cub. ft., and of fuel 7,700,000 cub. ft. The resin industry has shown a steady expansion in the Kumaon Hills. A large number of sleepers was supplied to railway companies last year. The surplus revenue of the year was 45,700*l.* In the Punjaub irrigated plantations are in course of formation, and a new resin factory has been erected with an up-to-date plant capable of dealing with 40,000 maunds of crude resin annually. The out-turn of timber last year was 5,900,000 cub. ft., and of fuel 17,200,000 cub. ft. The net revenue was 38,000*l.*

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Hull Coal Traffic.—A further decline in the fuel dealt with at the port is reported for the month of August. A total of 298,243 tons was exported, which is a decrease of 130,000 tons on the corresponding period of last year. The aggregate for the year up to date of nearly 2,250,000 tons is fully 1,000,000 tons less than the figure for the same period in 1915. For August, the foreign trade, excluding supplies to the Admiralty and Allied Powers, was 98,919 tons, or a weekly average of 25,000 tons. This shows a big reduction on last year, when the August weekly returns approached 60,000 tons. The principal decreases were: France, 625,000 tons; Denmark, 120,000 tons; Sweden, 65,000 tons; Norway, 40,000 tons; South America, 60,000 tons; and Holland, 20,000 tons. Only in one case was an increase reported, viz., that of Italy, who received 60,000 tons above her usual quantity. The Denaby and Cadeby Main still continues to be the principal contributor to the port, although the return for last month revealed a decline of 3,000 tons.

South Yorkshire Coal Trade.—The strong position in steam fuels is still maintained and works are receiving ample supplies. An irregular condition prevails in the export section, although the position is steadier than a week ago. Stocks are being accumulated by the large firms, railways and gas companies for the busier winter months. Neutrals are not taking large tonnages, and prices are easing off. Gas fuels are quickly absorbed under contract, and more business is transacted in the open market. A considerable amount is going to inland works, and shipments are also on a large scale, especially to France. There is a quieter tone in the inquiry for small coal, though slack is improving. Prices are steady. The condition of blast-furnace coke is still strong at maximum prices. In the house coal department there is increased activity, but the situation is complicated by the transport difficulties. Quotations: Best branch hand-picked, 20*s.* 6*d.* to 21*s.* 6*d.*; Barnsley best Silkstone, 17*s.* 6*d.* to 18*s.* 6*d.*; Derbyshire best brights, 17*s.* 6*d.* to 18*s.* 6*d.*; Derbyshire house, 16*s.* to 17*s.*; best large nuts, 15*s.* 6*d.* to 16*s.* 6*d.*; small nuts, 15*s.* to 16*s.*; Yorkshire hards, 16*s.* 6*d.* to 17*s.* 6*d.*; Derbyshire hards, 16*s.* to 17*s.*; best slacks, 12*s.* to 13*s.*; seconds, 10*s.* 6*d.* to 11*s.* 6*d.*; smalls, 8*s.* to 9*s.*

Iron and Steel.—Something like a settled condition has now been secured in the metal market, and the new basis of prices shows considerable change on the previous ones. Lincolnshire foundry and forge qualities are marked at 92*s.* 6*d.* and 90*s.* respectively, with delivery here, as against the former tariffs of 91*s.* 3*d.* and 90*s.* 3*d.* Derbyshire makers are also demanding these new figures, thus requiring an advance of from 2*s.* 6*d.* to 3*s.* on both forge and foundry brands. The new terms seem to be fairly acceptable, and buying has been on a much heavier scale than has been the case for a month past. Hematites continue to come forward in full supplies, and one effect has been a cheapening of the products. Whereas West Coast were originally 136*s.* to 140*s.*, delivered at Sheffield works, they are now obtainable at the much reduced figure of 127*s.* 6*d.* East Coast numbers, which are also in greater request, are now purchasable at 122*s.* 6*d.*, a reduction of nearly 5*s.* Local manufacturers are not in favour of the new regulations for the control of steel supplies, and steps are to be taken to get them modified. It is asserted the conditions laid down hamper progress and even restrict the output of munitions, for it is found that no steel, other than crucible, can be bought unless the purchaser has the necessary permit, reference number, and indicates the class of work for which the commodity is required. There is no apparent improvement in the steel billet position. The scarcity is seriously felt, especially as there has been delay in the delivery of American parcels. Swedish supplies are falling away still more. High-speed steel manufacture remains brisk, and there is every indication that all qualities of tool steel will be in big request for a considerable time ahead. Cutlery manufacturers have War Office and Admiralty contracts well in hand, but apart from export business they are unable to undertake other orders. Overseas business continues on a large scale, the latest indents including steel, tools, cutlery, machetes, knives, sheep shears, hardware, files, and wire ropes.

THE MINERAL WEALTH OF BRITISH COLUMBIA.—The annual report issued by the Ministry of Mines of British Columbia for the year ending December 31, 1915, contains interesting information on the mineral wealth of the province, as is afforded by the statistics which it gives of the output of various minerals over a period of years ending with the year 1915. We reproduce the yield for last year:—

			Value $.
Gold, placer	ounces	38,500	770,000
Gold, lode	,,	250,021	5,167,934
Silver	,,	3,366,506	1,588,991
Lead	pounds	46,503,500	1,939,200
Copper	,,	56,918,405	9,835,500
Zinc	,,	12,982,440	1,460,524
Coal	tons of 2,240 lb.	1,611,129	5,638,952
Coke	,,	245,811	1,475,226
Miscellaneous products			1,571,181
			$29,447,508

In regard to iron ore, the report states that no material advancement has been made in the utilisation of the numerous deposits throughout the province; at present there is no market in the province for iron ore, and, as a consequence, very little development work has been done. There are, undoubtedly, a number of iron ore deposits in different districts which are of considerable size and, as a rule, very free from injurious elements.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Glasgow Pig-Iron Market.—No fresh development regarding business in the Glasgow pig-iron warrant market falls to be noted—affairs remaining meantime at a complete standstill. While the stocks of pig-iron are being continually reduced, those in store in Glasgow are still reported as at 1,000 tons.

Sulphate of Ammonia.—An arrangement having been come to between the Sulphate Association and the Board of Agriculture, quite a number of the makers of sulphate have agreed to sell 60 per cent. of their make at 15*l.* per ton until the end of September, notwithstanding the fact that the market value is very much in advance of this figure. Indeed, at the moment, makers are easily getting 17*l.* 10*s.* per ton for export orders.

Scotch Steel Trade.—Mr. Lloyd George's recent visit to the Verdun front, and his inspection of the large store of shells and other war material which our Government has now been able to establish in France, is adding a further impetus to the workers in the West of Scotland at present engaged on its production. The demands of the Allied Governments continue insatiable, and while the pressure for delivery of the necessary supplies remains at its present high level, it is interesting to note that every available resource is being taken advantage of in order to maintain the requisite output. With the exception of the orders being executed for and despatched to the Allies, practically no export business is being put through, the strictness of the Government restrictions being very severely felt in this direction, as also in connection with the ordinary mercantile trade. As things stand it would almost seem as if the strenuous conditions which have now existed for some considerable time were daily becoming more accentuated, so insistent are the requirements for the purposes of the war. The position of the home trader whose stocks are now sadly depleted is disastrous in the extreme, for it is absolutely impossible for him to have his orders executed, or even considered. Perhaps the greatest activity in the steel-making establishments centres round steel for shell bars, which is being turned out in extraordinary quantity. Plates and sections of all classes are also much in demand. Prices are well maintained, the tendency certainly being towards higher rates. Ship plates are still quoted about 15*l.* per ton; boiler plates, 16*l.*; while angles for export are now fully 14*l.* 10*s.*

Malleable Iron Trade.—No change falls to be recorded in connection with the malleable iron trade, every establishment being so fully occupied with Government contracts that it is quite out of the question for makers even to consider the claims of their ordinary mercantile business. In fact it is confidently asserted that the orders at present in hand are sufficient to keep the different "shops" actively employed for at least ten months. Under existing circumstances no guaranteed date for delivery can be assured. Quotations for "Crown" bars are much on the level of last week—14*l.* 5*s.* per ton and upwards for export and 14*l.* 12*s.* 6*d.* or thereabouts, less 5 per cent., for home delivery.

Scotch Pig-Iron.—In the Scotch pig-iron trade the greatest activity exists, the demands on Government account meaning that the entire output is so speedily taken up that nothing is available for the ordinary consumer, whose claims are completely set aside in the meantime. Both hematite and foundry iron, especially the No. 1 brand, are in full demand, and every effort to increase the output is being made. As time goes on licences are becoming more and more difficult to obtain, the authorities being determined to have complete control of the distribution of all grades of pig-iron in order to ensure adequate supplies for Government requirements. Prices remain very steady.

Soldiers and Munition Work.—A very important pronouncement has just been made by the Scottish Command with reference to the employment of soldiers on munition work. It is pointed out that firms desiring the release of any man or men must, primarily, apply to the Ministry of Munitions, who alone can grant the necessary permission. Hitherto, in most cases, such requests have been submitted to the officer commanding the unit to which the men were attached, but this has given place to so much unnecessary delay that it has been deemed advisable to put the matter on a proper footing. When an application is made to the Ministry of Munitions, with the least possible delay due consideration will be given to the amount and the urgency of the work being undertaken on Government account, as well as to the skill and qualifications of the men whose services are required, after which, if the military authorities are willing, the transfer may be carried through.

CEMENT IN RUSSIA.—Although the Russian cement industry has been several times described as having to contend against considerable difficulties, both the number of factories and the production show a rapid increase, as will appear from the following figures:—

	Number of Factories.	Production. Barrels.
Beginning of 1916	67	(1915) 31,500,000
,, 1914	57	21,200,000
,, 1913	41	13,200,000
,, 1912	36	11,000,000

During the last three years the number of cement factories in Russia has consequently increased by 86 per cent. and the production of cement also by 86 per cent. Twelve cement factories have been obliged to stop work on account of the war or because they are situated in occupied districts; the aggregate production of these 12 factories amounts to 4,400,000 barrels.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—A steady though not very extensive business is passing in Cleveland pig-iron. The Control Board continue to allocate supplies in such a way that all legitimate home needs are met and some surplus is left for shipments. Hope is expressed that the restriction up to September of deliveries to Scotland will be removed shortly and that permission will be granted for arranging sales for October delivery to customers North of the Tweed. For home consumption, No. 3 Cleveland pig-iron, No. 4 foundry, and No. 4 forge, all stand at 87*s.* 6*d.*, and No. 1 is put at 91*s.* 6*d.*; whilst for export No. 3 is 97*s.* 6*d.*, No. 4 foundry 96*s.* 6*d.*, No. 4 forge 95*s.* 6*d.*, and No. 1 102*s.* 6*d.* Whilst the foregoing are the recognised market rates, No. 3 has been sold to France at 95*s.*, at which figure sales to Italy are also reported to have been made.

Stocks of Pig-Iron.—Stocks of pig-iron are changing very little just now. On no fewer than six days this month no alteration has been reported in the quantity of Cleveland pig-iron held in the public warrant stores here, and the stock now stands at 15,019 tons, composed of 14,983 tons of No. 3 quality, and 36 tons of other kinds of iron deliverable as standard. Since the beginning of the month 666 tons of No. 3 and 350 tons of standard iron, a total of 1,016 tons, have been withdrawn from the stores.

Hematite Iron.—There is little or no change in the East Coast hematite branch of trade. Makers are fully booked to the end of the year, and are not disposed to commit themselves further ahead, and there are practically no stocks, so that new business is very difficult to arrange, but deliveries on running contracts are understood to be well maintained. For home use, and for shipment to France, Nos. 1, 2 and 3 are 122*s.* 6*d.*, and for general export 140*s.* and upward is quoted. Any prompt lots available for shipment would readily command 142*s.* 6*d.*

Shipments of Iron.—September shipments of pig-iron promise to be on a satisfactory scale. So far this month they compare very favourably with August clearances and are considerably heavier than the despatches for the corresponding part of September last year. Deliveries to France are good, and supplies to Italy show improvement, though the latter is taking considerable quantities of American iron. The granting of licences for shipment of Cleveland iron to Russia via Norway does not appear to have resulted in the despatch of cargoes, owing to difficulties of transport not having been surmounted. The possibility of the release of some pig-iron for export to neutral countries appears remote. Merchants hope for such concession and point out that certain neutrals sending valuable foodstuffs to this country are urgently in need of pig-iron, and would greatly appreciate even very small supplies.

Coke.—The continued heavy demand for coke for local consumption is met by a more than ample supply, with the result that prices show a tendency to ease, but they have not been quotably lowered. Average blast-furnace kinds still realise 28*s.* at the ovens, and up to 30*s.* 6*d.* at the ovens is asked for qualities low in phosphorus.

Manufactured Iron and Steel.—Though there is not the extreme pressure for delivery of Government work that there has been, manufacturers of finished iron and steel are still kept very busily employed on war work, and they continue to pay little attention to the numerous ordinary commercial inquiries that are in the market. Prices keep very firm. The following are among the principal market quotations: Common iron bars, 13*l.* 15*s.*; best bars, 14*l.* 2*s.* 6*d.*; best best bars, 14*l.* 10*s.*; iron ship plates, 13*l.* 10*s.* to 14*l.* 10*s.*; iron ship angles, 13*l.* 15*s.*; iron ship rivets, 17*l.* 10*s.* to 18*l.* 10*s.*; packing iron and steel (parallel), 11*l.*; packing iron and steel (tapered), 13*l.* 5*s.*; steel bars (no test), 14*l.* 10*s.*; steel ship plates, 11*l.* 10*s.*; steel ship angles, 11*l.* 2*s.* 6*d.*; steel ship rivets, 20*l.*; steel joists, 11*l.* 2*s.* 6*d.*; steel hoops, 16*l.* 10*s.*; steel strip, 17*l.*; heavy steel rails, 10*l.* 17*s.* 6*d.*; and steel railway sleepers, 12*l.*

NOTES FROM THE SOUTH-WEST.

Cardiff.—Steam coal has been as scarce as ever and markets have generally continued strong. The requirements of the authorities have shown no reduction, and the pressure from exporters has, if anything, been growing keener, in consequence of anxiety to get steamers away. For early delivery only odd parcels have been available, rarely more than 200 tons each; and holders of these parcels have been able to command substantial premiums. Small coal has been almost as scarce and strong as large. Patent fuel and coke have shown continued strength. The best Admiralty large steam coal has been, to some extent, nominal; secondary qualities have made 43*s.* to 45*s.*; Monmouthshire Black Veins, 44*s.* to 45*s.*; ordinary Western Valleys, 44*s.* to 44*s.* 6*d.*; Eastern Valleys, 40*s.* to 43*s.*; best bunker smalls, 30*s.* to 31*s.*; and cargo smalls, 20*s.* to 25*s.* per ton. In bituminous coal best households have made 25*s.* 6*d.* to 26*s.* per ton at the pits; No. 3 Rhondda large, 42*s.* to 44*s.*; smalls, 32*s.* to 33*s.*; No. 2 Rhondda large, 35*s.* to 37*s.*; and No. 2 smalls, 25*s.* to 26*s.* per ton. The latest quotation for patent fuel has been 44*s.* to 45*s.* per ton. Special foundry coke for export has brought 62*s.* 6*d.* to 65*s.*; good foundry coke, 60*s.* to 62*s.* 6*d.*; and furnace coke, 50*s.* to 55*s.* per ton.

Western Trade Matters.—Delegates from the Swansea Chamber of Commerce to the Board of Trade, on the limitation of coal prices and coal freights to Italy, have reported to a special meeting of the Chamber. They state that the opinion of the Board of Trade representative is that a new committee will be necessary to deal with the matter, but that the committee for French trade can cover it with a few additional representatives. The maximum rates, it is thought, will be fixed slightly above current levels. The scheme is not expected to come into operation until October.—North's Navigation Collieries (1889), Limited, have changed hands. These collieries have an output approaching 1,000,000 tons per annum, and the capital raised is 650,000*l.* Last year the dividend paid on the ordinary shares was at the rate of 12½ per cent. per annum. The members of the old board of directors have retired, with the exception of Mr. L. Evan-Thomas; and a new board has been formed, with Lord Rhondda for chairman; the other new directors are Mr. A. Mitchelson, Mr. H. Seymour Berry, and Mr. J. Wentworth Smith, the son of the retiring chairman, Mr. J. J. Smith, who was connected with the undertaking for upwards of 50 years. Lord Rhondda is to be invited to become managing director as well as chairman; and it is proposed to appoint Messrs. Lysberg, Limited, of Cardiff, selling agents; the sales policy of the company will thus be brought into harmony with that of some of the principal South Wales collieries. It is stated that the various arrangements contemplated will involve an outlay of 1,250,000*l.* An offer has been made to holders of North's Navigation ordinary 1*l.* shares to acquire their shares at 2*l.* each, the intending buyers being a group including Lord Rhondda and Mr. A. Mitchelson. Mr. Mitchelson has offices in Cardiff and London, and he was associated with Lord Rhondda in the recent deal in the ordinary shares of D. Davis and Sons. In the present deal Mr. Mitchelson acts conjointly with Mr. H. Seymour Berry, of Cardiff. The retiring directors will receive a lump sum of 10,250*l.* as compensation for their loss of office; this 10,250*l.* is not to be paid out of the assets of the company. No staff changes are proposed. As a result of the arrangements contemplated, Lord Rhondda becomes chairman of four collieries practically adjoining each other. North's Navigation, 1889, is regarded as one of the most valuable colliery properties in South Wales, "with considerable possibilities of development."—Mr. F. A. Gibson, secretary of a district coal and coke supply committee appointed by the Board of Trade for South Wales and Monmouthshire, states that after careful consideration of all the facts and circumstances the committee has decided that all the colliery companies in the district shall be instructed to supply the same merchants with the same quantity of house coal each month, from September to December inclusive, as was supplied in the corresponding months of last year. The scheme has received the approval of the Board of Trade and merchants must not deviate from it. Householders are urged to exercise the strictest economy in the use of fuel.—Baldwin's, Limited, have acquired the Cribbwr Fawr Colliery, between Pyle and Port Talbot. The colliery, which is in a virgin area, has already a substantial output. Baldwin's had previously extensive mineral interests in the district, including the Aberbaiden and Ton Phillip collieries, near Kenfig Hill, the Coytrahen Park Colliery, &c. Baldwin's are the owners of the Panteg steelworks and the Albion Road Colliery, near Newport; they, further, own the Aberbaiden and Pentre Slants and the Bryn Navigation collieries; and in an adjoining valley they have the Caytraken Park Colliery. The Cribbwr Fawr Colliery produces both house and manufacturing coal.—It is denied in South Wales that there is any intention to form a coal ring and to put up prices.—The directors of the Town Line recommend a final dividend of 16*s.* per share for 1915–16, making a total of 25 per cent. for the year, carrying forward 2,747*l.* A steamer which is being built for the company by Messrs. Murdock and Murray, Limited, is expected to be delivered in November.

AMERICAN SHIPBUILDING.—Steel merchant vessels were building, or under contract to be built, in American private shipyards at the commencement of the new American fiscal year (July 1) to the number of 385, of an aggregate displacement of 1,225,784 tons. The Senate Naval Committee has reported the Naval Appropriation Bill, which provides for the largest naval building programme in American history. The new battleships, battle cruisers, scout cruisers, and other types of warships and auxiliaries proposed to be built number 157, with an approximate displacement of 855,000 tons. The building of these vessels will involve an aggregate estimated outlay of 588,000,000 dols. Of the new ships proposed to be built, 66, of an aggregate displacement of 382,000 tons, are to be commenced as soon as practicable, and the remainder before July, 1919. The shipbuilders of the United States have the prospect of several years of great activity before them.

AUSTRALIAN GOLD.—The decline in the production of gold in the Australian Commonwealth, which has now been noticed for several years, continued in 1915, the total output for the 12 months amounting to 1,942,835 oz. (fine), as compared with 2,048,905 oz. (fine) in 1914. The most serious decline occurred in Victoria, where there was a falling-off in the output of 80,638 oz. In Western Australia the shrinkage was 22,868 oz.; New South Wales showed an increase of nearly 1,000 oz. High wages and current conditions of working are regarded by capitalists associated with Australian gold mining as rendering the industry increasingly unprofitable. An award of the Commonwealth Arbitration Court made in December increased wages to an extent which renders it probable that as a result of the decision some of the gold mines of Victoria may be closed down.

LOCOMOTIVES, CLASSES "K 4 S" AND "L 1 S," FOR THE PENNSYLVANIA RAILROAD.

MR. J. T. WALLIS, GENERAL SUPERINTENDENT OF MOTIVE POWER.

(*For Description, see Page 244.*)

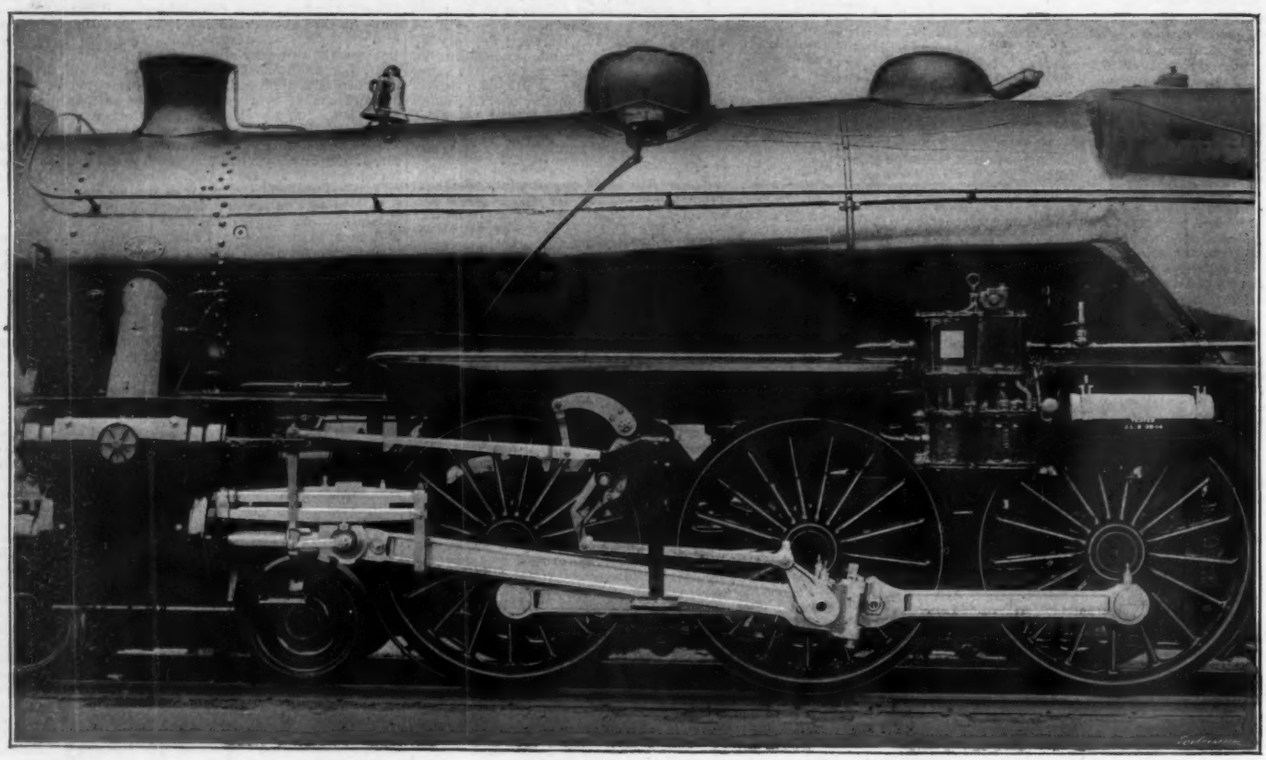


FIG. 166. CROSS-HEAD, GUIDE BARS, VALVE MOTION, &C., OF THE "K 4 S" CLASS.

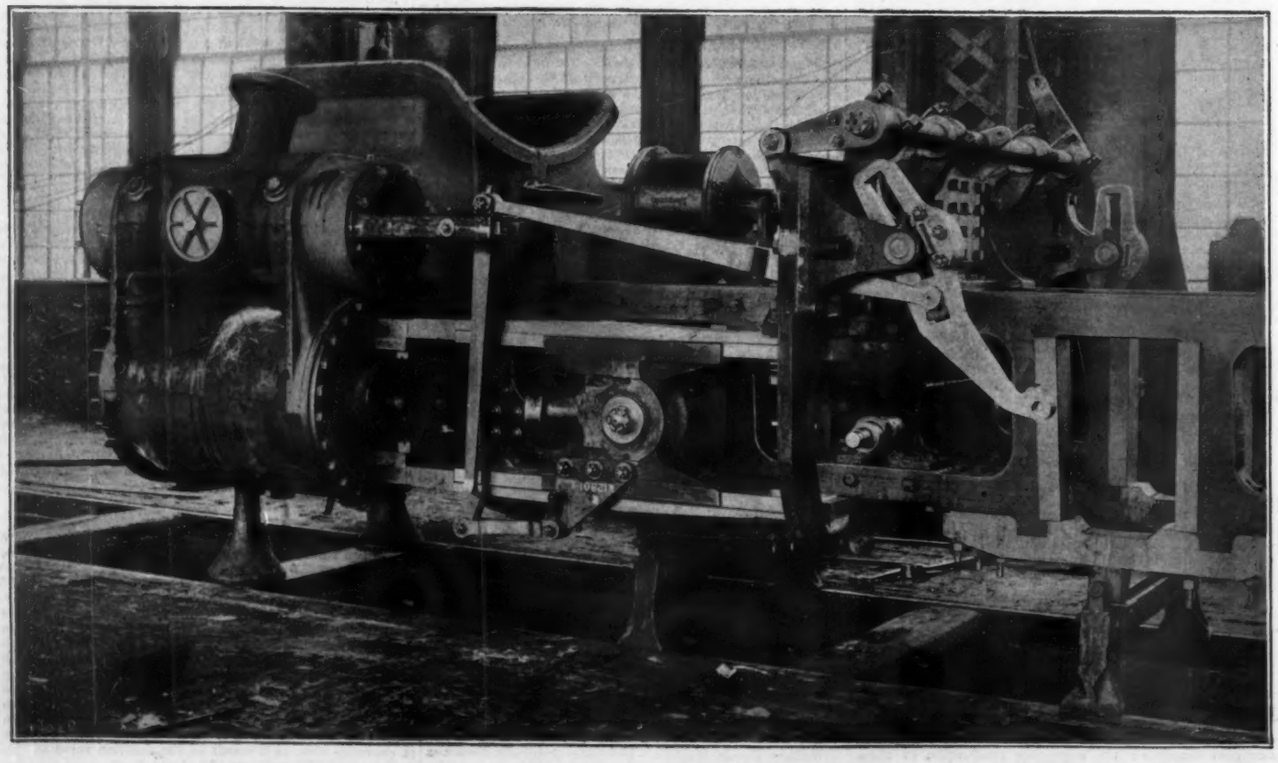


FIG. 167. CYLINDERS, CROSS-HEAD, GUIDE BARS, &C., OF THE "L 1 S" CLASS.

DETAILS OF LOCOMOTIVES OF CLASSES "K4S" AND

MR. J. T. WALLIS, GENERAL SUPERINTENDENT

(For Description see Page

Fig. 119.

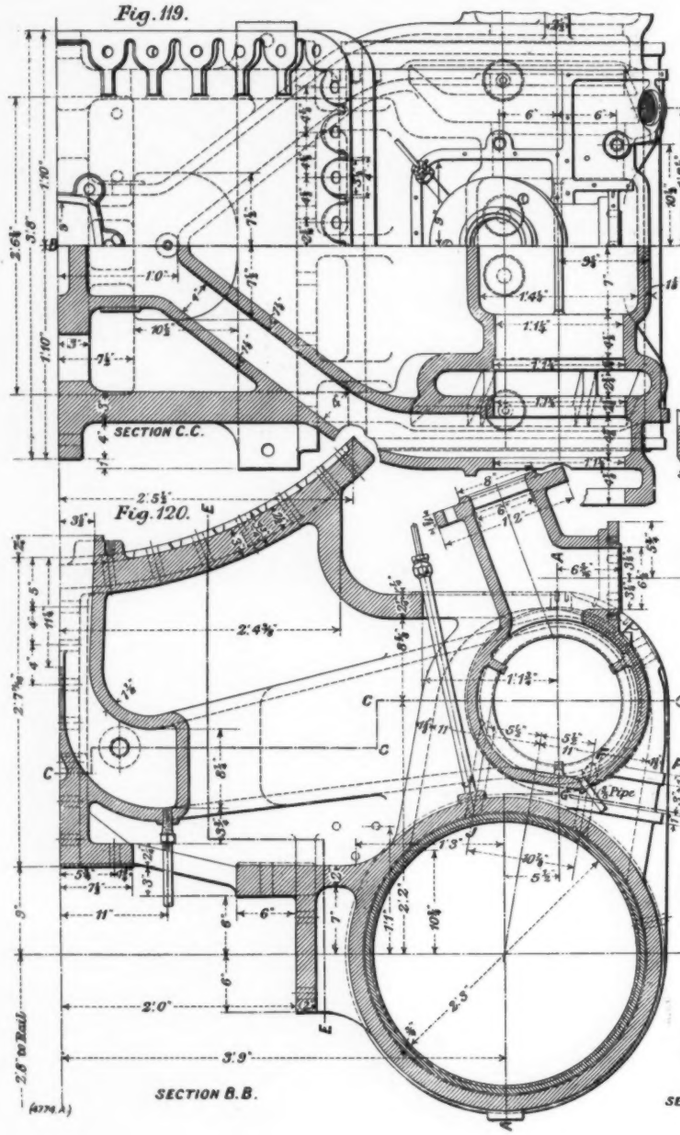


Fig. 120.

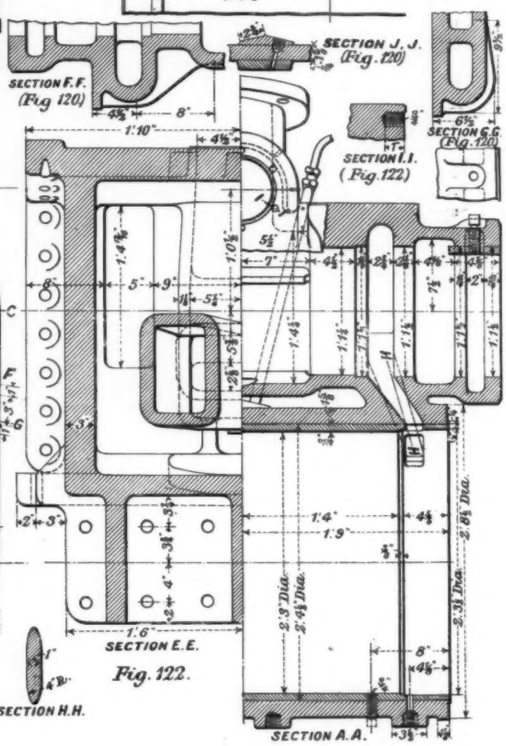


Fig. 121.

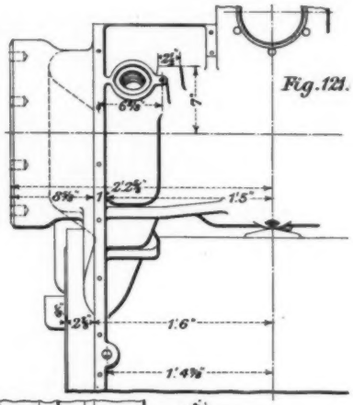


Fig. 122.

Fig. 123.

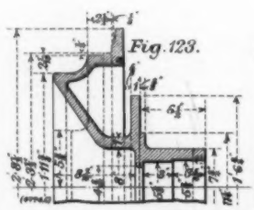
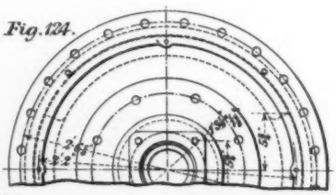


Fig. 124.



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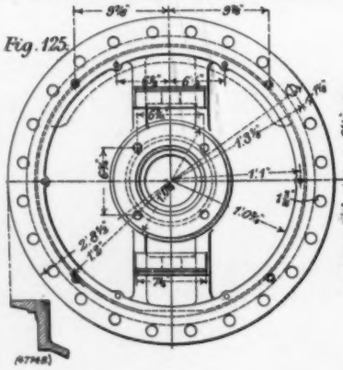


Fig. 126.

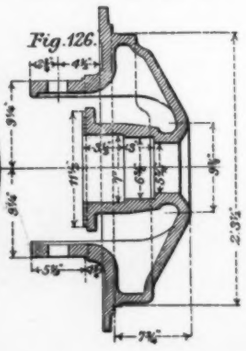


Fig. 127.

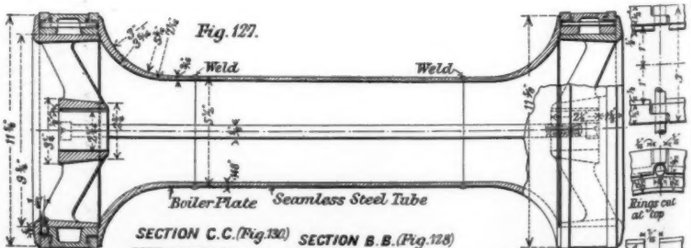


Fig. 128.

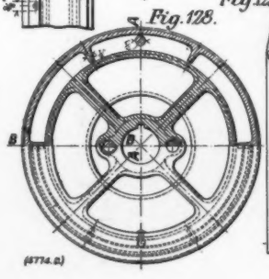


Fig. 129.

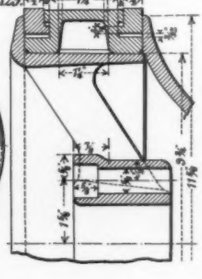
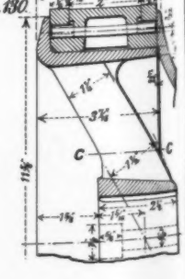


Fig. 130.



ND "L1S," FOR THE PENNSYLVANIA RAILROAD.

SUPERINTENDENT OF MOTIVE POWER.

(See Page 244.)

Fig.131. BEFORE SWAGING.

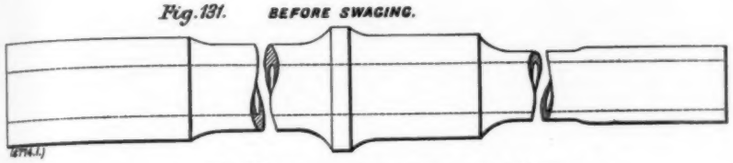


Fig.132. FINISHED ROD, FOR L.I.S. CLASS

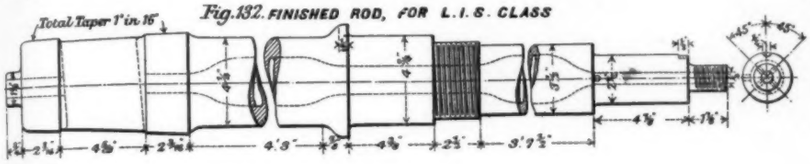
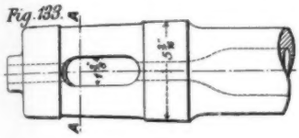


Fig.133.



SEC. A.A. Fig.134.

Fig.135.

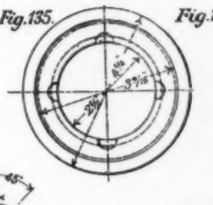


Fig.136.

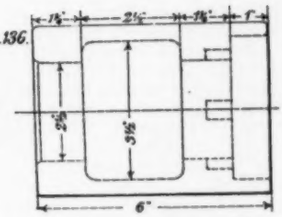


Fig.137.

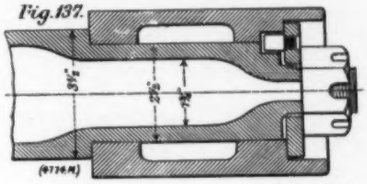


Fig.138.

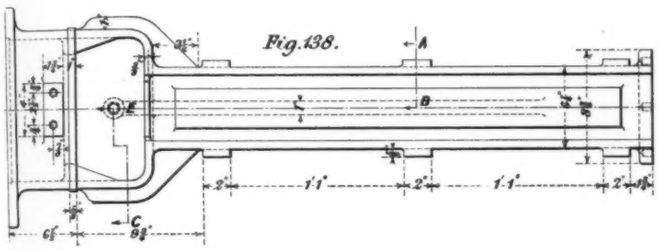


Fig.139.

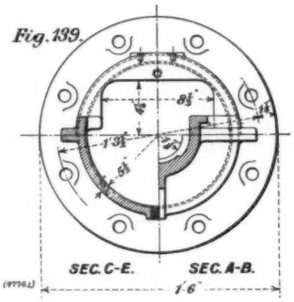


Fig.140.

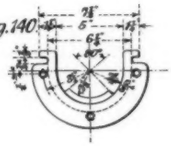
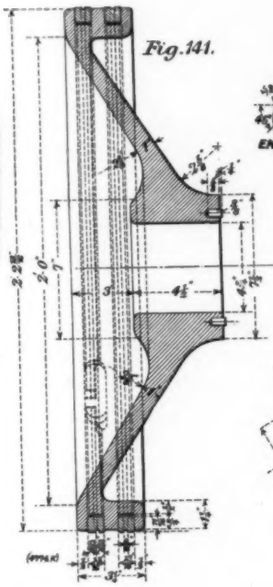


Fig.141.



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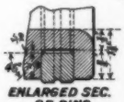


Fig.142.

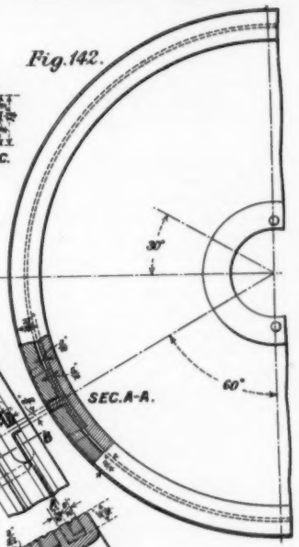


Fig.143. Fig.144.

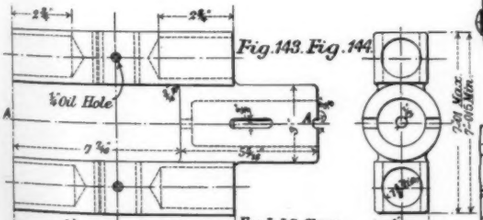
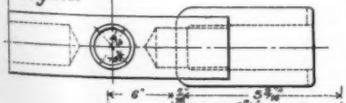


Fig.145.



SECTION AT A.A. Fig.146.

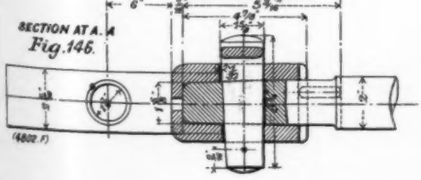


Fig.147.

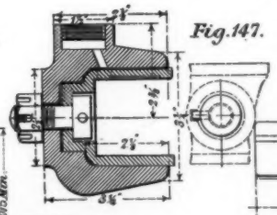


Fig.148.

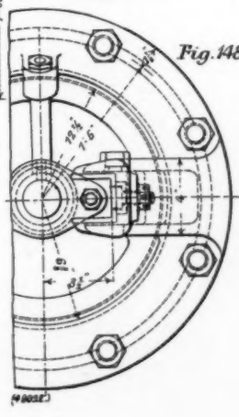


Fig.149. PLAN

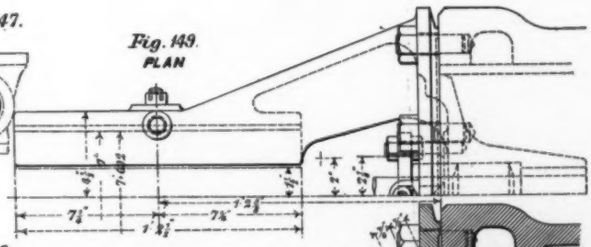
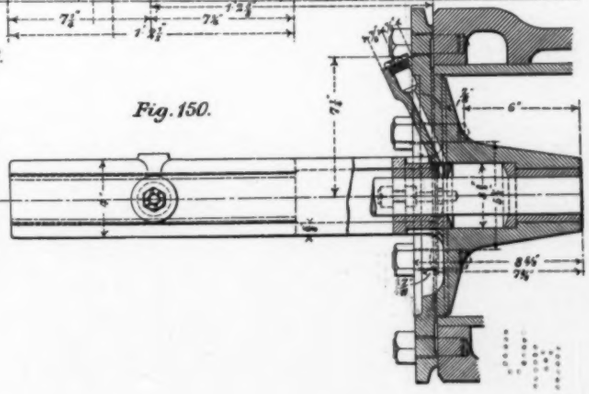


Fig.150.



AGENTS FOR "ENGINEERING."

AUSTRALIA: Gordon and Gotch, Limited, Melbourne; Sydney; Brisbane; Perth. Turner and Henderson, Sydney, N.S.W. T. Willmett and Co., Townsville, North Queensland. W. C. Rigby, Adelaide, South Australia. Melville and Mullen, Melbourne, Victoria.
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With a Two-Page Plate of the DETAILS OF LOCOMOTIVES OF CLASSES "K 4 S" AND "L 1 S" FOR THE PENNSYLVANIA RAILROAD.

NOTICES OF MEETINGS.

THE INSTITUTE OF METALS.—Wednesday, September 20, at 4 p.m. and 8 p.m., annual autumn meeting, in the rooms of the Chemical Society, Burlington House, Piccadilly, London. Sir George T. Beilby, F.R.S., LL.D., will preside. The following papers will be presented and discussed:—(1) "The Allotropy of Silver," by Dr. W. D. Helderman, Utrecht University, Holland. (2) "Note on Cadmium in Speiter," by Mr. W. R. Ingalls, New York, U.S.A. (3) "The Annealing of Arsenical Brass containing 61 and 62.5 per cent. of Copper. A Study of the Structure and Properties developed by varying the Rate of Cooling within the Transformation Range," by Mr. C. H. Mathewson and Mr. E. M. Thalheimer, Yale University, U.S.A. (4) "The Development of the Spelter Industry," by Mr. Ernest A. Smith, A.R.S.M., Sheffield.

THE IRON AND STEEL INSTITUTE.—Thursday, September 21, at 10.30 a.m. General meeting of members. Scrutineers will be appointed for the examination of voting papers for election of new members of the Institute. A selection of papers will be read and discussed (Nos. 6, 1, 4). The Council will give notice of amendment of bye-laws. Friday, September 22, at 10 a.m. General meeting of members. A selection of papers will be read and discussed (Nos. 3, 7, 5). The following papers are expected to be submitted for reading and discussion:—(1) "Some Properties of Ingots," by Mr. H. Brearley. (2) "Influence of Heat Treatment on the Thermo-Electric Properties and Specific Resistance of Carbon Steels," by Professor E. D. Campbell. (3) "Heat Treatment of Eutectoid Carbon Steels," by Dr. H. M. Howe and Mr. A. G. Levy. (4) "Steel Ingot Defects," by Mr. J. N. Kilby. (5) "Manganese Ores of the Bukowina, Austria," by Mr. Herbert K. Scott. (6) "Influence of Elements on the Properties of Steel," by Dr. J. E. Stead, F.R.S. (7) "Notes on (*a*) Nickel Steel Scale; (*b*) on the Reduction of Solid Nickel and Copper Oxides by Solid Iron; (*c*) on Effect of Blast-Furnace Gases on Wrought Iron," by Dr. J. E. Stead, F.R.S. (8) "Use of Meteoric Iron by Primitive Man," by Mr. G. F. Zimmer.

ENGINEERING.

FRIDAY, SEPTEMBER 15, 1916.

PATENT LAW REFORM.

LORD PARKER, in a recent issue of *The Quarterly Review*, writing of the industrial problems which will come up for consideration and solution at the conclusion of hostilities, refers among others to the problem of patent law, and says:—"We should endeavour to encourage new inventions and to secure that new inventions when made shall be brought into use at the earliest possible moment. Our patent laws are justified by the desirability of encouraging new inventions, but it is very doubtful whether they have that effect, while they are very often used to prevent new inventions being utilised at the earliest possible moment. In this connection we should reconsider and overhaul our patent laws."

Patent law reform is a subject in which we have always taken a great interest, and in the past we have advocated reform, and have indicated with a certain measure of success directions in which the law could be improved with advantage to the inventor and to the public.

We are glad to see that a judge having the professional and personal authority of Lord Parker has asserted the need for an overhauling of our patent law and has justified the necessity of laws for the protection of inventions. Many people are under the impression that patents are granted solely for the benefit of inventors: the impression is erroneous. The principles which underlie the granting of patents are well expressed in a passage which occurs in the argument of counsel for the defendants in a sixteenth-century lawsuit. The passage, which has obtained world-wide celebrity, is as follows:—"Where any man by his own charge and industry, or by his own wit and invention doth bring any new trade into the Realm, or any engine tending to the furtherance of a trade that was never used before, and that for the good of the Realm; that in such cases the King may grant to him a monopoly patent for some reasonable time, until the subjects may learn the same, in consideration of the good that he doth bring by his invention to the Commonwealth; otherwise not." Patents are therefore granted in the public interest, and though they are monopolies, they must not be used in a manner derogatory to the public welfare. Lord Parker points out that our patent laws are capable of being used in such a manner. We well know that that is the case, and we agree that the time for reform is now ripe. The question will have to be taken in hand by the legislature, and at a not very distant date, for one of the resolutions at the Paris Conference dealt with patents. The resolution was as follows:—"The Allies undertake to convene a meeting of technical delegates to draw up measures for the assimilation, so far as may be possible, of their laws governing patents, indications of origin and trade marks." The Governments of the allied countries have evidently realised that their laws are far from perfect and do not adequately protect inventors and, what is more important, the general public. The task of assimilating the laws of the several allied countries, so far as they concern patents, will not be an easy one, as the laws are very dissimilar, as is also the practice thereunder, though they are all based on the primary idea that the monopoly granted to the inventor for the disclosure of his invention will be for the good of mankind. In the past, the framing and administration of laws advowedly intended and designed to encourage inventors would seem as if, in some cases, no pains had been spared to introduce needless complication and uncertainty. If the laws of the several allied countries are to be assimilated, let there, at this favourable moment, be an attempt made to produce a good patent law, that is to say, one which will, on the one hand, offer every reasonable inducement to those possessed of inventions to introduce them into use at the earliest possible moment, and, on the other hand, will not deprive anyone of any liberty he has already properly enjoyed.

We cannot within the limits of an article specify and enter upon an adequate consideration of the various features we deem open to objection in our own patent laws and in the patent laws of our Allies, or even indicate and give reasons for the various details essential to a complete patent law, but we submit for consideration certain suggestions which we believe, if adopted, will be improvements. We do not put forward the suggestions as novel; on the contrary, some of them have been advocated for many years.

In this country an applicant is given the option of filing in the first instance either a provisional or a complete specification of his invention. This method of procedure is peculiar to Great Britain and her colonies and dependencies, other countries requiring an applicant to file a full specification of his invention, with claims, in the first instance. The assimilation of the patent laws of the allied countries will require either that the British system be adopted by all or abandoned by Great Britain. The abandonment of the system would, in our opinion, be a step in the right direction and would get rid of complications. The system has powerful advocates, who are not backward in urging its retention, but any advantages it may possess are overshadowed by its numerous and greater disadvantages.

At the present time the laws of Belgium, France and Italy do not prescribe an official examination as to novelty; Russia has an examination of a sort, and in this country there is an examination confined to the specifications of prior British patents. For years we advocated an examination scheme to ascertain whether the invention appeared to have been anticipated, regard being had to prior publications in the country, and we also advocated that the discovery of a publication deemed by the Patent Office authorities to anticipate the invention claimed by the applicant should not be a ground for refusal of the patent, provided that the applicant inserted in his specification a reference to such publication, with a clear statement of what he, nevertheless, claimed. An examination scheme on the foregoing lines was instituted by the Patents Act, 1902, and though it was limited to the specifications of prior British patents, it was better than no examination at all. The assimilation of the patent laws of the allied countries will be an opportunity for the other nations to adopt the scheme outlined above, though it should not be limited to the specifications of prior patents granted in the respective countries, but should include all publications in the respective countries. We do not, however, advocate that the technical delegates should draw up an examination scheme which will extend to the utility of the invention or require the applicant to prove that his invention is a step in advance. In Germany, such procedure is adopted, and it is notorious that an applicant is often put to great expense and trouble to prove that his invention possesses a new technical effect over what has been done before, and that if he fails to convince the examiner, the grant of a patent is refused. The difficulty of deciding whether one thing is an improvement on another, even with inventions in actual use, is very great, and to require an examiner

to decide from a mere examination of documents alone is demanding more than can be expected. It is true that the Patents Act, 1907, amended the examination scheme of the 1902 Act by giving the Comptroller power to refuse a patent in cases in which, in his opinion, the invention sought to be patented was identical with one already patented. Identity of inventions is a question of great difficulty, and though the Patent Office officials always act benevolently towards the applicant, we should like to see the power of refusing the patent as the result of examination taken out of their hands.

The introduction of an examination extended to publications in the country would require an amendment and extension of the law governing oppositions and would necessitate the inclusion of grounds permitting opposition to grant by reason of prior publication in the country of a full description of the invention and prior public use and sale of the invention in the country. The laws of some of our Allies do not provide for opposition to grant, and the inclusion of such a feature in their laws would be of advantage as tending to get rid of the necessity for invoking the aid of the Courts.

The term of the British grant is nominally 14 years: in practice it is much less. The term could be with advantage extended so that it approximates more nearly with those granted in other countries, which vary from 15 to 20 years. The British grant is practically the shortest of all patent terms; in practice it is reduced by the fact that its period runs from the date of application and that a patentee is debarred from suing for infringement before the actual grant of the patent, which may be 15 months or more after the date of the application, and then only for infringements committed since the date of the acceptance of the complete specification, which may be 12 months after the date of the application.

As the law now stands the Comptroller has power to revoke a patent, and he has also power to revive a patent which has been allowed to lapse, but he has not power to extend the life of a patent which has run its full term. That power is reserved to the Courts; patentees who have applied for prolongation of their patent rights have some idea of the large item called by solicitors "costs." If the Comptroller has the powers mentioned it is inconceivable why he should not have the further power. The necessary machinery would be simple and the costs would be kept down to a small figure, all of which would be desirable, not only from the point of view of the patentee, but also from that of the public who may feel justified in opposing the prolongation.

There are many articles which are quite novel in themselves and of considerable utility which it is quite impossible to protect under the Patents Act on the ground of want of subject-matter. On the other hand, they are at present almost incapable of being registered as designs, as they cover something more than the mere pattern, shape or configuration of the article or the ornament thereof. The law should, and could be easily, amended so that protection would be granted for useful models or articles, somewhat on similar lines to what is granted in Germany under the designation "Gebrauchsmuster." Such petty or design patents might be granted on payment of a fee less than that payable on ordinary patents, without an examination as to novelty and for a term of, say, five years, renewable, on payment of a second tax, for a further and similar period. Such a form of protection would be largely used by inventors, and if an inventor chose to apply for a petty or design patent when he should have applied for an ordinary patent, the public will not be the loser, for the inventor will have a shorter period of protection and his protection will be limited exactly to what he has shown in his drawings.

Our concluding suggestion is that the law should be strengthened as regards patent agents. As the law now stands patent agents are registered and are under control. The definition of a patent agent is so weak that the law can be evaded by anyone so inclined by the adoption of some such term as "Patent Expert." Many persons hold themselves out as patent agents without actually describing themselves as such. It is only too true that many of this class are disreputable persons, and that in many cases money entrusted to such persons by confiding inventors is misappropriated; in addition to this there is the serious fact that many self-styled "Patent Experts" are totally unqualified to perform properly the work they undertake. The law could easily be amended by defining a patent agent as any person, firm or company acting for another in obtaining patents for which he charges or is paid for his services. Unfortunately in these days there is an absurdly exaggerated dread of curtailing individual liberty and creating monopolies. To insist upon reasonable qualification and the observance of common rules of honesty as a condition of being permitted to practise is surely not to create a monopoly in the true sense; for no one is debarred from qualifying and practising, and surely no right-minded person can desire liberty to obtain money from his fellow men by false pretences.

THE PEAT BOGS AND PEAT INDUSTRY OF CANADA.

IN continuation of the wise policy pursued by the Canadian Government of informing the world of the extent of the resources of the country and of the opportunities for local development, the Department of Mines has recently published the further results of an elaborate inquiry into the situation, content and character of the peat deposits scattered over the more eastern portions of the Dominion. The information apparently is confined to that collected in 1913, and the report is to be read in connection with those that have appeared earlier. These reports do not appeal solely to the capitalist or the enterprising pioneer. The Mines Department, recognising that the introduction of science into practical affairs is a feature of the present age, have combined pure with applied science. The Department is to be warmly congratulated on attacking the general problem with vigour and resourcefulness, contrasting very favourably with the indifference and apathy exhibited by the home Government towards a similar problem in Ireland. This report is the more welcome as of late years peat has attracted considerable attention on account of the possibilities it offers for generating a gas suitable both for power and fuel. The peat industry is widening. When totally unsuitable for other purposes peat containing in some instances as much as 60 to 70 per cent. of incombustible constituents can now be used to great advantage in the production of fuel for power generation. Mr. Aleph Anrep, the compiler of the report, does not enter, however, into these new fields of usefulness that Caro, Frank and others have exploited, but treats rather of the methods of collecting and handling peat, dried and undried.

Particulars are given of the detailed examination of ten peat bogs in the Province of Ontario, three in Quebec, six on Prince Edward Island, and eight in the Province of Nova Scotia, with results of the analysis of the peat found in each. These reports are accompanied by photographic illustrations of the plants found in the bogs investigated that will be appreciated by botanists and palæobotanists, since they serve to show the constituent organic growths from which the peat in the respective bogs has been formed. The careful classification and description of the plants will, moreover, give information on the condition of alkalinity and acidity of the soil on which they were grown, and assist a correct understanding of the circumstances that have contributed to the distribution of vegetation over the earth's surface. The character of the surrounding environment will explain to some extent the process by which the progress of vegetable decomposition has been arrested. It is not impossible but that the presence of acid conditions, inimical to the growth of micro-organisms of decay, has played a great part in the suspension of decomposition and produced an excellent peat. In some instances described, as in the Stoco peat bog in Ontario, the existence of marl is mentioned, a substance which would indicate alkaline waters, giving rise probably to the resulting formation of an inferior kind of peat. The subject is full of interest, though this may not be the place to discuss it, and since we cannot return to this section, we can simply record our satisfaction that a careful examination has been made *in situ*, and that the authorities have consented to devote so large a space in the report to purely scientific ends.

Much of the information concerning the peat bogs takes a tabular form and will be sufficiently illustrated if we confine our attention to one district. The conditions in Prince Edward Island are tolerably uniform and may be selected. During 1913 a comparatively small area, embracing 5,356 acres, was under examination, but these contain nearly 25,000,000 cubic. yards of workable peat. The weight of fuel, containing 25 per cent. of moisture, amounts to nearly 1,250,000 tons, and that of litter peat, with 20 per cent. of moisture, is only slightly less. In passing from volume to weight an element of uncertainty is introduced, but as a rule a drained bog is reckoned to furnish from 120 to 200 lb. of dry peat substance per ton. The reduction of volume due to simple drainage is large. In tolerably compact bogs averaging 5 or 6 ft. in depth the decrease in depth due to drainage will equal 1 ft. or more. In pecuniary value the rough peat material differs considerably, but in the United States peat moss litter was selling in 1913–14 at from 5 to 6 dols. a ton. The well-humified peat suitable for the manufacture of peat fuel probably fetches a higher price, but locality and costs of transportation must be determining factors. Canada, as we have seen, can produce both kinds, but in some places the deposits are shallow and not well adapted for working on modern lines with large plant. Knots and stumps in the peat itself are a frequent hindrance, and an irregular surface is a disadvantage in working on most approved methods, requiring long lines and levelled fields.

As an example of analyses of different peat samples we may select those collected from the Province of Quebec, where a larger area gives a greater variety. The composition is fairly uniform: the percentage of fixed carbon is approximately 29, that of volatile matter 66, and of ash 4 per cent. Small quantities of sulphur and nitrogen are also found. The latter is important, for on its amount depends the possibility of recovering ammoniacal salts on a commercial basis. Unless 1½ per cent. of nitrogen, calculated on an absolutely dry peat, is present, the by-products are not worth collecting. The calorific value, expressed in calories per kilogramme gross, is approximately 5,000, or 9,000 British thermal units, per lb. Such peats are generally to be utilised to advantage for the production of gas, and the operation is likely to be profitable if the peat containing about 30 per cent. of moisture can be obtained at a cost not exceeding 1½ dols. per ton.

The most judicious method of treating peat has been the subject of much discussion, the Canadian authorities adhering generally to the air-drying process, while in Sweden and in Northern Europe the wet carbonizing process is preferred. In this report the author makes but very brief references to the latter method, into which very considerable improvements have been introduced by De Laval and others. The well-known process of Ekenberg, which dispenses with air drying, has been discredited, one might say condemned, for in earlier reports the Canadian Department of Mines has stated that notwithstanding large funds having been placed at the disposal of various investigators in order to enable them to demonstrate the economic value of the plan, not one ton of peat fuel has been manufactured on a commercial scale by means of the process. This remark refers apparently to the original process, patented by Ekenberg, for rendering the water of peat more freely expressible by heating the material under pressure, a process in which great difficulty has been experienced in removing the water in an efficient and economic manner. Since that time, however, several patents for dewatering peat have been applied for, and if the utmost value is to be derived from this natural source, whether for fuel, for power, or for recovery of by-products, it would seem that a more elaborate treatment must be applied than is at present practised in Canada. No doubt there is a market for air-dried peat, which this report is intended to encourage, but the industry does not seem to be pushed vigorously beyond the preliminary stage.

Judging from the description of the plant erected at the Alfred Peat Bog (Ontario), where enterprise is given full play under Government auspices, the

arrangements aim at no more than the provision of efficient apparatus for the excavation of peat, and its transportation to drying grounds, with automatic expedients for the cutting of the peat into suitable blocks and exposing them to the air at a minimum of labour. This simple process is not without its failures. No thoroughly reliable method seems to have been evolved for preventing the blocks crumbling to waste. The peat used to be stacked in small cubes and left on the ground to dry down to a content of 25 per cent. moisture, and then shipped directly to the consumers. After considerable experience, it is now recommended that the blocks should be quickly placed under weather-proof covering, as the dampness under the peat does not evaporate, but causes the bricks to disintegrate. This concession to uncertain weather conditions points to a decided improvement, but in Canada a deeply rooted objection is entertained against the use of mechanical pressure to force out the moisture at an early stage in the preparation. In an earlier report the Brune and Horst process, which consists in mixing hard dried compressed peat with the raw, freshly excavated, and submitting the mixture to a continuous and gradually increasing pressure, was not approved, and from the slight reference to the method in this report it is to be inferred that the same adverse judgment holds. Artificial drying is discouraged, partly, we imagine, because valuable constituents of the peat may be expelled with the water during pressure, and also on account of the expense necessarily incurred in employing heat for evaporation. It must be admitted that in simple pressure between perforated plates solid material passes away with the water, reducing the bulk, and if some fibrous material, as felt, is used as a filter, the greasy nature of the peat tends to objectionable clogging. This trouble has been much reduced in modern apparatus, and, further, by availing ourselves of the principle of regeneration rendered possible by the exothermic reaction which takes place within the peat when heated to a temperature above 180 deg. C., such economies can be introduced that the objection on the ground of expense loses its force.

The De Laval process, referred to only very briefly in these pages, has apparently much to recommend it, though it relies on the one hand on the wet carbonizing process of Ekenberg, and on the other adopts mechanical pressure. Swedish experts have reported very favourably on the method to their Government, who have granted a subsidy for the construction of plant capable of turning out 10 metric tons of peat bricks daily. This decision points to an increasing demand for peat in Sweden, where its use in the form of a powder is popular and gaining in favour as a fuel. The Swedish Steam Boiler Society has recently conducted a series of firing tests in their boilers, with the view of determining the relative value of peat powder and coal. The result showed that with peat powder 75 per cent. efficiency was obtained, and with coal 64·2 per cent. This gives the relation between peat powder and coal, with the respective effective fuel values of 4,110 calories for peat, and 6,755 calories for coal, of 1·4 of peat powder equal in fuel value to one of coal. This somewhat unexpected result is said to be due "to the more thorough mixture of the peat powder with air, and probably to the instantaneous regulation of the amount of air and powder required for variation in steam consumption. When burnt in a properly constructed furnace, a higher temperature of combustion and better efficiency is obtained per calory than from coal." Some corroboration comes from Denmark, where, owing to the difficulty of obtaining coal since the war, peat has been largely used for fuel, with satisfactory results. No coal has been imported since the outbreak of hostilities, and consequently the price of stored coal became prohibitive for many industrial purposes. Peat is easily obtained as a marketable fuel, and the demand rose to gigantic proportions. Manufacturers compelled to use peat by the scarcity of coal have reported that they are very well satisfied with the substitute, notwithstanding that the price of peat has risen approximately 50 per cent. In Russia the consumption of air-dried peat fuel has increased, and the demand falls only slightly behind that of crude oil, while coal, as a fuel, occupies the third place. In that country, too, the prices of coal, crude oil, and wood have all risen, causing a revival of interest in the native peat fuel industry.

These displacements of the ordinary course of trade, side issues of the great war, that deflects normal commercial intercourse into strange channels, directs attention to the improvements that have been effected in peat manufacture. The excavation of the raw material, apparatus for accelerating and cheapening its production, the creation of fresh markets, all acquire new importance, and since the direction in which the development is proceeding is one in which the Canadian form of the industry is particularly concerned, Mr. Anrep and the Mines Department are doing good work in collecting details of such improvements, as well as of the patents designed to encourage or simplify the manufacture. The dissemination of this information among those who are in a position to turn it to account should prove a great assistance and stimulant. The descriptions of these patents, accompanied with abundant illustrations, for handling raw peat and its subsequent treatment form not the least interesting portion of the report.

Among the patents of purely Canadian origin is the description of a machine for treating peat from its excavation till it is submitted to the effects of sun and air in a continuous operation. The peat extracted from the bog not only has its roots and fibres removed, but is subjected to such intense cutting and rending between movable and stationary knives that it can be passed through a kneading and mixing apparatus, working the raw peat into a compact mass of uniform consistency. Under this treatment the peat yields up much of the water stored in the cells, and acquires plastic qualities facilitating the moulding into required shapes, whether cake, strings or blocks. Another apparatus feeds the moulding frames with an equal thickness of the mixed peat, and by a suitable mechanism delivers the moulded form without injury or deterioration. The object is to secure a relatively heavy and firm product that will give little waste and resist the deleterious effects of rain and moisture.

The spreading of the peat on the drying field, involving sometimes transportation to a considerable distance, must be a relatively costly process, the weight of the moisture to be carried exceeding that of the valuable solid material. Mr. Moore, of Ontario, describes a very complete apparatus designed to facilitate this onerous process of depositing and spreading the crushed and pulped peat on the drying field in thin convenient layers. The machine, which can be fed through a hopper or similar device, is propelled forward through a suitable motor, which furnishes both the means of locomotion and forces the material into required shapes. This machine could be used in connection with that of Mr. Anrep, as the main feature of the device consists in distributing the prepared and masticated peat to the moulds. This is accomplished by a number of revolving screws or worms, which operate alternately and intermesh, an arrangement that maintains a uniform feed and prevents any longitudinal movement of the peat in the trough other than that communicated by the distributing screws. The moulds are made to taper slightly, thus offering a resistance to the passage of the peat, so that it is pressed into a compact mass and discharged in continuous ribbons from the rear of the machine on to the ground. As each mould discharges a separate stream, the air has free access to three sides of each ribbon, promoting the rapid drying of the peat. The consistency of the paid-out ribbon or blocks may be varied by regulating the speed of the machine to that of the feeding screws, and by suitable adjustment of the feeding and travelling speeds a product of any desired consistency can be ensured.

A more ambitious scheme for utilising peat, and one which demonstrates greater possibilities, is foreshadowed in a patent granted to Messrs. Testrup, Rigby and Soderlund. This is based on an improvement of the Ekenberg carbonising process, and aims at producing a substantial excess of fuel, in the solid or gaseous state, after satisfying the needs of the process. The applicants state that dewatering a carbonised peat to such an extent that the moisture is sufficiently reduced as to make the residue available for gasification cannot be carried out successfully in one operation. For economical treatment, a fairly solid cake that will contain about 65 per cent. of water must be produced in a filter press, and, in a second stage, this cake must be submitted either to a mechanical pressure, reducing the water to 50 per cent., or dried by contact with the hot products of combustion resulting from heat generated in the process. After attaining this degree of dryness the peat is divided into two parts, one of which is conveyed to a gas producer, which supplies the gas consumed in heating the carbonizer. The other part of the material, when further dried, is conducted to a briquetting press, from which the briquettes are delivered as articles of commerce. The gas in the producer is further treated by suitable means for the recovery of ammonia in the form of ammonium sulphate. In many cases it is possible for the filter press effluent, after having been utilised to pre-heat raw peat entering the carboniser, to be concentrated by evaporation and the solids made to produce sugars, acetic acid, &c., as additional by-products. The installation can be conveniently modified to generate electrical energy. In that case the excess producer gas not needed for the heating and power requirements, and after being treated for the recovery of ammonia, can be made to drive internal combustion engines coupled to electric generators.

A wider field of usefulness is indicated by such processes than is suggested in the Canadian plan of simply providing peat for fuel after air drying, when a considerable amount of moisture will still be present. This tolerably solid fuel can, however, be baked in by-product recovery ovens, producing a valuable coke and possibly an increase in nitrogen compounds. Many other ways have been suggested for getting rid of the water while preventing any material decomposition of the peat, and much more ingenious treatment will be devoted to this object.

Some processes described here look very hopeful and suggestive, but it is doubtful if they have passed beyond the experimental stage. Among these may be mentioned one which seeks to utilise peat by converting it into a manure after treating it with micro-organisms capable of producing ammonia. This process is connected with the researches of Professor Bottomley, but has not been received with ardour by the agricultural interests. That a great future lies before the peat industry is certain, the potential wealth is far too great to be neglected, but the precise direction novel developments will assume can at present only be conjectured. Meanwhile Canada is more than justified in looking closely after an asset of great value, in considering the forms in which it can be put on the market, the character and the provision of the necessary transport facilities required to handle a bulky product, and in awakening interest in an undeveloped industry.

ACCIDENT TO THE NEW QUEBEC BRIDGE.

ENGINEERS the world over will be greatly shocked at the new catastrophe at Quebec which has occasioned the loss of 25 lives. No intelligible account of the disaster has as yet reached this country, the only hypotheses which appeared in any way admissible from the earlier reports would attribute the disaster either to malice or to hidden flaws in some part of the hoisting tackle. Some of these attributed the accident to the failure of a jack, but, as will appear in the sequel, this contingency had been provided for, and would have given rise to nothing more serious than some delay. From a reliable source we learn that the accident arose from the crushing of the bearing which supported, during the lift, the south-west corner of the span. This bearing had carried its load without any evidence of weakening for six weeks, and its sudden failure is for the present inexplicable. The new bridge is located on the same centre line as the original structure which collapsed during erection in 1907, and has the same maximum span of 1,800 ft., but the position of the piers has been slightly shifted. It is a cantilever structure designed by the St. Lawrence Bridge Company, a corporation formed *ad hoc* by a union of the Dominion Bridge Company with the Canadian Bridge Company. The bridge is intended to accommodate two lines of railway and

two footpaths. The designed live load was 5,000 lb. per foot run on each track plus two E 60 engines placed so as to produce maximum strains. A wind load of 30 lb. per square foot of the exposed surface of the two trusses, plus 1½ times the elevation of the floor was provided for. Suitable provision was also made for the wind load on moving trains and for snow loads.

The Royal Commission which reported on the collapse of the original structure noted as a contributory cause to the disaster the exceedingly inadequate provision made for professional advice. This criticism had been taken very thoroughly to heart, and a very strong board of engineers was appointed to supervise the design and execution of the work. A large number of very expensive tests were also made of models of the principal compression members of the bridge, these models being, moreover, amongst the largest struts ever tested. These tests gave very satisfactory results, which are confirmed by the way in which the cantilever arms have resisted the shock of Monday's disaster.

An outline view of the bridge is reproduced in Fig. 1 and shows that the 1,800 ft. span is composed of two cantilever arms each 580 ft. long and a central suspended span 640 ft. long. Very special consideration was given to the erection of the structure, an engineer of exceptional experience in such work being appointed to prepare the plans and superintend the operation. For various reasons it was decided that the central span should not be built out in the way usual with cantilever bridges, but should be erected on staging a few miles downstream and put in place by floating it to the bridge site on barges and then lifting it. This was undoubtedly a somewhat bold operation, as the span weighed about 5,000 tons, and the velocity of the stream attains at times 7.3 m.p.h. This feat—apparently the really difficult part of the process—was successfully accomplished. The span had been lifted clear of the scows and raised 30 ft. out of the total 150 ft. required when the bearing at the south-west corner gave way. The enormous impact resulting from the fall of over 1,200 tons through a space of several inches caused the whole structure to break away and fall, and it now lies submerged in 200 ft. of water. Cable reports say that in spite of the great depth of the channel some hope is entertained of salving the span. Some 90 workmen and officials were on the span at the time of the accident, and of these some 8 or 10 have lost their lives.

On this and the opposite page we reproduce from *Engineering News*, of New York, drawings which illustrate the means provided for lifting the span into place, and we are indebted to an article by Mr. A. J. Meyers in the same journal for much of what follows.

As noted above, the stream velocity at the site of the bridge attains at times a speed of 7.3 m.p.h. At about one hour after high water, however, the direction of flow reverses, and it was arranged that the truss should arrive at the bridge site just half an hour after high water, in which case the speed of the stream could be counted on as not exceeding 3 m.p.h. for a period of about one hour.

On arrival at the site the span was moored to the

THE QUEBEC BRIDGE (NEW DESIGN)

Fig. 1.

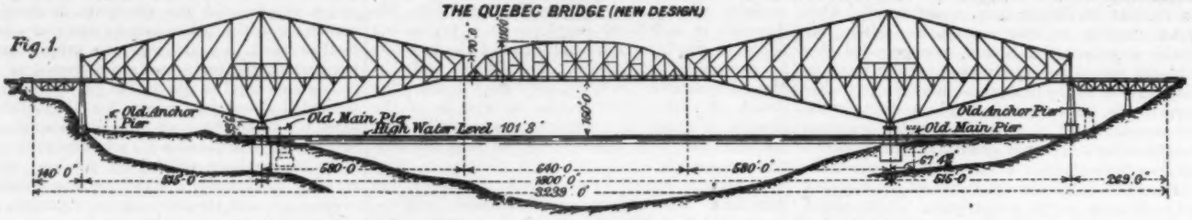
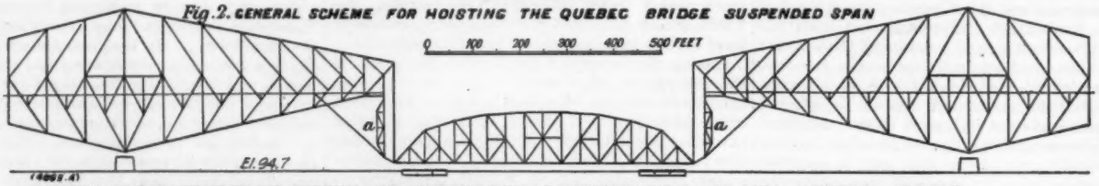


Fig. 2. GENERAL SCHEME FOR HOISTING THE QUEBEC BRIDGE SUSPENDED SPAN



DETAIL OF ARRANGEMENTS FOR MOORING AND HOISTING THE SUSPENDED SPAN OF THE QUEBEC BRIDGE

Fig. 3.

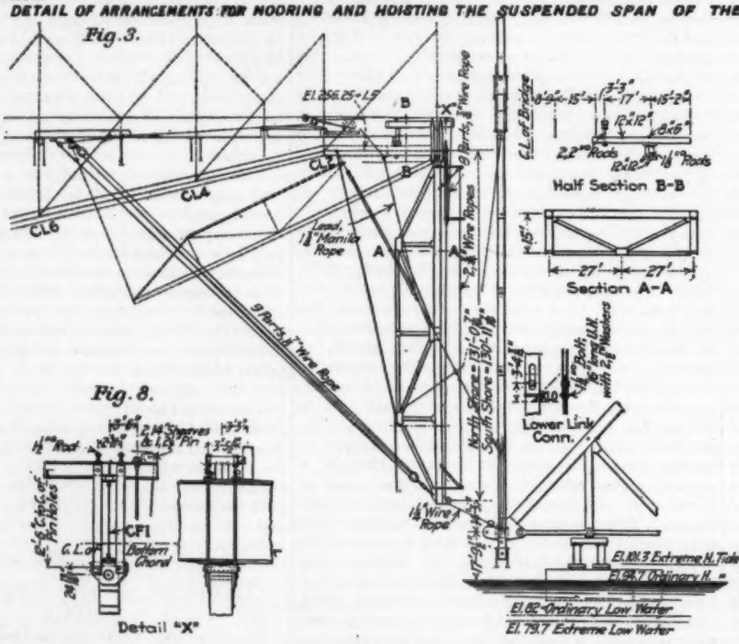


Fig. 4.

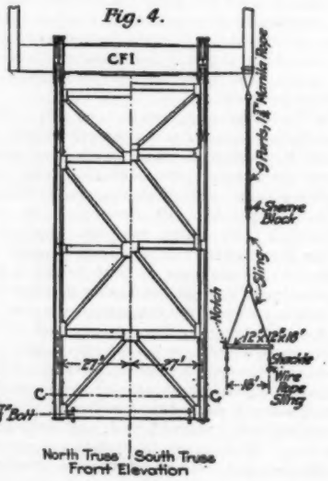


Fig. 8.

Fig. 5.

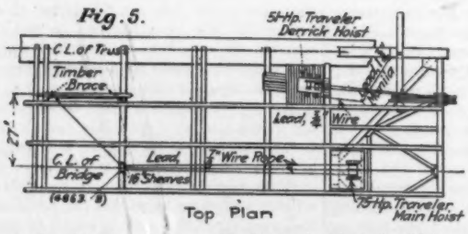


Fig. 6.

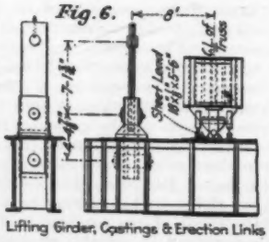
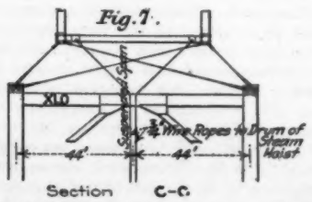


Fig. 7.



frames shown at *a a*, in Fig. 2. These frames were stiff enough in the up and down stream direction to take any load that might be imposed by the current or by a light breeze, but in the fore and aft direction of the bridge were merely held back by the ropes shown in Fig. 3, page 260. By hauling on these the mooring frames could be raised almost to the floor level of the cantilever arm and thus cease to obstruct the fairway. Under the ends of the span special lifting girders were provided, and the span rested on rockers secured to these girders. It was apparently one of these rocker bearings which failed. It will be observed that this rocker was bedded in sheet lead. This practice is not without objection, and in the case of masonry may be positively dangerous, owing to the bursting pressure developed by the flow of the metal. Here, however, the surfaces separated by the lead were of steel, which can resist heavy bursting pressures. Just outside these rockers the girders were coupled to chains built up of 30-ft. links, 30 in. wide by 1¼ in. thick, and secured to each other by 12-in. pins. The upper ends of these chains were secured by pins of the same size to one or other of two jack girders, which are shown in position in Figs. 9 and 10, above. A set of these jack girders was provided for each of the four corners of the span. The lower jack girder was suspended from the top of the cantilever arm as indicated, and served to support 1,000-ton hydraulic jacks, which in their turn carried the upper jack girder. In all, eight of these jacks were provided, two at each corner of the span arranged as indicated in Figs. 9 and 10.

These jacks had a travel of some 2 ft. Three sets of holes for 12-in. pins were provided in both jack girders. The lifting chains passed down through these girders, and each 30-ft. link of the chain was bored at 6-ft. intervals to take a 12-in. pin. In the jack girders holes for the same-sized pins were provided at 2-ft. intervals. Assuming the jacks fully down and the chain secured to the upper girder by means of the 12-in. pins, the jacks were run out to their full stroke of some 2 ft. This lifted the span and at the end of the traverse brought a pin hole in one set of links opposite one set of the pin-holes in the lower jack girder. Pins were then inserted and the jacks slacked back, thus transferring the load to the lower jack girder. So soon as the strain was thus eased, the pins in the upper jack girder were taken out and the jacks run back down to the bottom of their stroke, carrying down with them the upper jack girder. This done, the chains were again pinned to this upper jack girder and the pins in the lower one removed and the cycle of operations repeated. At the end of each 30-ft. lift the chain was shortened by the removal of one set of links. Seventy-five of the above cycles were required to complete the total lift, and it was expected that this operation would take about 20 hours.

As is well known, there is always a possibility of hydraulic jacks failing, and in this case the working pressure was 4,500 lb. per square inch. To provide against this contingency, a second set of screw jacks were fitted. These had counter-weighted screws, thus facilitating their use, and were operated by hand to follow up the girder as it lifted. Hence, even if one of the hydraulic jacks did give way, the load would still be held until the defect could be made good.

The plan of operations appears free from objection in principle, and much thought had been given to the details of its execution. To facilitate the insertion and removal of the 12-in. pins the holes both in the links and the jack girders were made slightly oval, measuring 12⅞ in. vertically and 12¼ in. horizontally in the case of the links, whilst in the case of the holes in the jack girders the side clearance provided was 1 in. and the vertical clearance 1⅛ in. The pins were, moreover, counter-weighted to make them more easily handled.

The total load lifted, inclusive of the tackle, was 5,142 tons, and the nominal maximum stress caused by this on the material of the links was 20,000 lb. per square inch. In a perfectly elastic material the true maximum stress would, of course, be about three times this figure, but the links, being of ordinary structural steel, would have been capable of yielding enough to "average" the stress fairly well over the section. Tests specially made to this end indicated that the chains could carry their intended load without risk.

As will be seen, provision had been made to provide against the failure of a jack letting the load down with a run and thus causing a complete collapse. It was never, however, anticipated that a failure could occur in the bearings on which the span rested. The drawings we reproduce are not sufficiently detailed to permit of any estimate being made of the strength provided, but in view of the exceptional care it is hardly likely that an error was made here. Hidden flaws or malicious injury seem for the present the most probable cause of the disaster.

JACKING EQUIPMENT FOR HOISTING THE QUEBEC SUSPENDED SPAN.

Fig. 9.

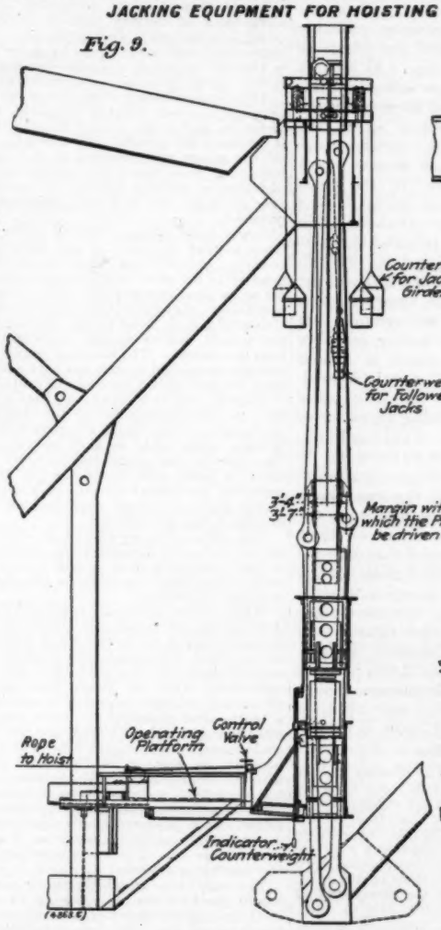
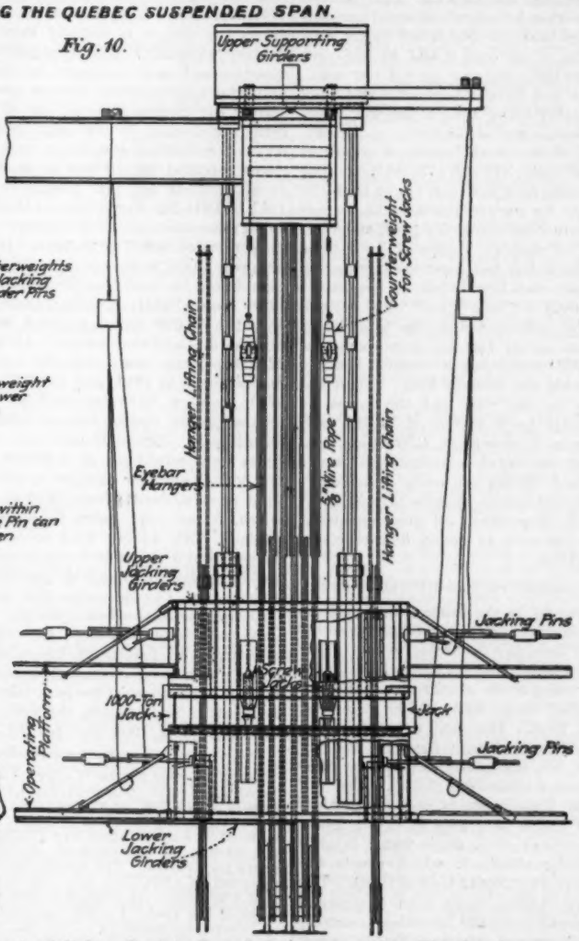


Fig. 10.



NOTES.

LOSSES OF MERCHANT SHIPPING.

THE most authentic information available regarding losses of merchant shipping are those published by Lloyd's Register of Shipping. The return issued this week deals with the quarter ending with March last, the intervening time being required for securing accurate information from all countries in the world. The total losses from all causes, from the war, misadventure and other natural conditions, for this quarter, are 316 vessels of 612,519 tons. This is less than in preceding quarters, due in part to war losses. The total, however, of war losses for the quarter is not by any means as great as in some of the earlier periods of the war. The war losses of all nations for the quarter ending

March include 137 vessels of 389,994 tons, more than one-third of these being those of other countries than Britain. In the September quarter of last year, for instance, the total war losses were 229 vessels of 462,553 tons, while in the December quarter of last year the war losses were 167 vessels of 409,587 tons, so that it will be seen that there is a falling-off. The losses in the British fleet from all causes are about double the normal volume, but, notwithstanding this, the percentage of loss for the March quarter is only 1.71 per cent. of the tonnage owned, representing considerably less than 7 per cent. per annum. This one may almost regard as a fair proportion, and equal only to the normal rate of loss in the merchant fleet of most of the other maritime nations of the world. The neutral countries are suffering heavily, because, from this return, it is seen that the Dutch are losing now at the annual rate of between 9 and 10 per cent. of the tonnage owned, Norway over 6 per cent., Spain 7.6 per cent. and Sweden between 4 and 5 per cent. In the quarter under review the war losses of Holland were 8 vessels of 34,355 tons; of Norway, 12 vessels of 21,159 tons; of Sweden, 4 vessels of 3,996 tons; and of Spain, 3 vessels of 5,981 tons. The fact that the German fleet has been swept from the high seas is proved by the circumstance that their war losses were only 2 vessels of 474 tons, and their total losses from all causes 5 vessels of 5,058 tons. Of our Allies, France has lost most heavily during this quarter, their war loss being 16 vessels of 47,408 tons; but on the other hand only 5 small craft were lost by misadventure, the total losses being 48,407 tons. Italy lost by war operations 5 vessels of 8,102 tons, but 8 vessels lost by misadventure double the tonnage lost. Japan lost no vessels owing to the war, and the losses by natural causes made up 9 vessels of 39,835 tons. Russia lost by war 3 vessels of 4,760 tons, and 8 others, making the total loss from all causes 11,661 tons. These figures are quite satisfactory and show that the submarine menace of the enemy is not achieving by any means all they hoped for, and is certainly not such as should disturb either ourselves or our Allies.

COAL-MINE FATALITIES IN THE UNITED STATES.

The returns received by the Bureau of Mines from the State mine inspectors show a gratifying decrease in the number of fatalities occurring in and about coal mines in the United States during the calendar year 1915. According to the statistics compiled by Mr. Albert H. Fay there were 2,266 fatalities, against 2,454 in 1914. The rate per 1,000 men employed was 2.95; the lowest figure so far had been 2.71 in 1898, but the actual number of killed (2,266) was the lowest since 1906 (2,138). The coal production of the United States was 518,000,000 tons in 1915 and 513,525,477 tons in 1914; based upon the production of 1915, there was 1 fatality per 228,600 tons of coal mined, which excels the best figure so far known (220,945 tons in 1912). The 11 mine disasters (killing more than 5 persons) of 1915 were responsible for 262 fatalities. Among the causes for the improved safety are better inspection and enforcement of rules; realisation of the danger by the miners, due to the educational campaign conducted on their behalf; more general use of safety lamps and of permissible explosives; humidifying of dusty mines; first-aid and rescue-training. The statistics concerning coal-mine fatalities in the United States since 1870, also given by Mr. Fay, deal with records of very unequal lengths and conditions; in some States records are available for more than 25 years, in others only for five years, and the laws, practices and productions vary very much. But the 54,457 fatalities tabulated permit of drawing some conclusions. The fatalities increased in the years from 1897 to 1907, when they culminated. That increase is only partly explained by in—efficient inspection. Conditions of operating the mines were changing in all these years; the mines grew deeper, there was a strong influx of foreign, inexperienced labourers, not understanding English, and a start was only made in appointing safety committees. Coal-mine disasters account only for 12 per cent. of the fatalities, and 297 disasters up to 1914 claimed altogether 7,590 victims. The total number of fatal accidents due to explosives was 3,675, this figure representing on average about 20 years' working; 17 per cent. of these accidents were due to handling and transport, 24.8 to premature blasts and short fuses. Electricity is charged with having caused 710 fatalities; 49 per cent. of these were due to direct contact with trolley wires, 7 per cent. to tools and bars striking the trolley wires; contact with mining machinery, *i.e.*, faulty insulation, probably caused 4 per cent. of the accidents. Fall of roof is altogether the most serious source of danger; 48 per cent. of the fatalities are ascribed to this source, which causes more loss of life in relatively safe mines than in mines where the condition of the rock constantly warns the miners and officials; this group of accidents has fortunately shown a decline in late years. Haulage was charged with 13.3 per cent. of the victims in 1871 and with 15.5 per cent. in 1915, and in this group the danger is actually increasing, probably because electricity and compressed air admit of speedier and more extensive haulage. As regards non-fatal accidents the figures are still more uncertain for various reasons, one of them being the great differences in different States as to the way of collecting statistics; many accidents are never reported at all, and in most States, if not in all, reports are not obligatory. In the years 1911 to 1914 Mr. Fay estimates that 150 out of each 1,000 miners received minor injuries disabling them for periods of from 1 to 20 days. In metal mines 50 men per 1,000 were seriously injured in 1914 (incapacitated for more than 20 days), and 270 men per 1,000 were slightly injured; these figures concern only the 75,000 men employed underground, not surface, mill and shop hands. Altogether, probably 22,900 persons were seriously injured in United States mines in 1914, and 114,500 slightly injured. With respect to responsibility, Mr. Fay refers to the official South African mining statistics of recent years. There 56 per cent. of the fatal accidents were considered as inherent to the work, 17 per cent. each were charged to officials (ignorance, want of care, disobedience) and to the men themselves, 5 per cent. more to other men (not the victims). We do not wish to comment on these figures; but it should be borne in mind that coloured unskilled labour plays a large part in African mining. Finally, Mr. Fay discusses the question whether statistics should be based on the number of men employed, tons produced, or other figures, and he decides in favour of hours actually worked. These numbers vary strongly; but 2,000 working hours per year seems to be a fair average, though in Colorado, for instance, the mines were operated for 268 days in 1906 and for 206 days in 1911.

TRADE OF NEW SOUTH WALES.—The oversea imports during April were valued at 2,686,463*l.*, and show an increase of 645,206*l.*, or 31.6 per cent., as compared with the corresponding month of last year. The total for the ten months, July to April, was 27,424,985*l.*, an increase of 3,753,692*l.*, or 15.9 per cent., in comparison with the figures for 1914-15. The oversea exports during April amounted to 3,061,677*l.*, being an increase of 817,446*l.*, or 36.4 per cent., as compared with the corresponding month of last year. For the ten months, July to April, the exports amounted to 34,723,135*l.*, being an increase of 11,397,654*l.*, or 48.9 per cent., compared with the same period for 1914-15.

MELBOURNE HARBOUR WORKS.—The Melbourne Harbour Trust has recently outlined a scheme of improvements which it is proposed to carry out in order to secure a greater depth of water and increased dock facilities. The expenditure involved in a programme extending over the next 10 years is 2,800,000*l.*, divided as follows:—Deepening waterways, 800,000*l.*; wharves and cargo accommodation, 1,500,000*l.*; plant, 200,000*l.*; general improvements, 150,000*l.*; approaches, 50,000*l.*; contingencies, 100,000*l.* Contracts have been entered into with the Victorian Government for the construction of a suction dredger for 93,000*l.*, and a tug for 26,482*l.* At present the dredging and towing plant owned by the Melbourne Harbour Trust comprises 35 vessels.

UNITED STATES SUBMARINE.—We read in the *Iron Trade Review*, Cleveland, Ohio, that the Fore River Shipbuilding Corporation, Quincy, Mass., has commenced the construction of the "Schley," which will be the largest submarine in the United States Navy. She is to have a length of about 270 ft. over all. Her ordinary radius of action is given as 2,500 miles without replenishing her fuel tanks. If necessary, she will be able to carry oil to take her twice that distance. Diesel engines will give her a surface speed of about 20 knots, and electric motors a submerged speed of about 11 knots. Using only her storage batteries, the "Schley" will be able to travel completely submerged for a day. The vessel will cost about 1,400,000 dols.

ELECTRIC POWER DISTRIBUTION.*

By CHARLES H. MERZ.

"It appears that . . . the coal should be converted . . . into a form in which it is most generally applicable to all purposes without exception, and in which it is most easily applied to all our wants, and is at the same time in a form in which it is most difficult to waste or use improperly.

"We are therefore forced to the conclusion that the only complete and final solution of the question is to be obtained by the conversion of the whole of the coal which we use for heat and power into electricity, and the recovery of its by-products at a comparatively small number of great electricity producing stations. All our wants in the way of light, power, heat and chemical action would then be met by a supply of electricity distributed all over the country." [Extract from Presidential Address of Mr. S. Z. de Ferranti to the Institution of Electrical Engineers in 1910.]

The fuel and other economies and the industrial advantages of dealing with electricity supply for the country as a whole in a comprehensive manner—although appreciated and acted upon by many of those who are in the electric supply business—are not generally realised to-day by the industrial community or by the State.

The compact nature of our industrial districts and their proximity to each other as compared with those of other countries, such as the United States and Germany, makes it economically possible and advantageous to deal with all the power requirements of the community in each industrial area from inter-connected electrical power distribution systems tapping all sources of power, however scattered, and delivering electrical energy wherever required.

Power undertakings (electric power companies) have been started in most of the industrial areas of the country, and if these were developed throughout the country to the same extent as the system which has been for some time in operation on the north-east coast, it is estimated that the resultant economies in coal consumption would, in the near future, amount to 25,000,000 tons per annum, and eventually to 50,000,000 or 60,000,000 tons per annum. The immense importance of this to the country is realised even if one only considers the revenue from the sale of this quantity of coal if it were exported.

Another way to look at it is, that if the present industrial power requirements of the country were supplied as cheaply as they could be from such a comprehensive system, there could be such an expansion of industry that present day power requirements might in no great time be more than doubled. Yet there would be no necessity for increased coal consumption for the simple reason that under such conditions we could use our coal at least twice as efficiently.

The economical generation of electricity implies the use of the largest possible prime movers and the running of such machines at as steady a load as possible, since only under these conditions is the highest possible coal economy attainable.

While on the north-east coast and also in some other districts the generation and supply of electrical power is being developed on correct lines, it is still broadly true to say that, as regards the country as a whole, the requirements of each municipal area are dealt with separately, with the result that the average size of generating machine employed is certainly not more than a tenth—and probably not more than a twentieth—of what it ought to be. Under such conditions economical coal consumption is impossible. The result is cumulative because, on account of the small size of generating machine employed in public stations and the consequent low economy, manufacturers, railway companies, and other large power users in many districts are still compelled to run power plants of their own, and the use by many manufacturers of their own plant further reduces the average size of power-generating machines, taking the country as a whole.

The only way in which public supply stations can secure the business of supplying all the manufactories in their neighbourhood is to have generating machines much larger than the largest individual manufacturer could find use for.

If instead of each municipal area being dealt with independently, there were one uniform inter-connected electrical power distribution system throughout each industrial area, as we now have practically throughout the north-east coast district, just as there is one railway system throughout the country with a uniform gauge, it is clear that, on account of the magnitude of the resultant load, it would be possible to secure the following results:—

1. The largest and most economical generating machines could be installed.

2. These could be located where large sites are available and land is cheap; where coal and water facilities are good; and in the best position, having in view the probable eventual power requirements of the whole community, including factories, railways and domestic users.

If, on the other hand, each municipal area is dealt with independently, it is clear that in many cases the sites on which the power generating plant is installed must necessarily be cramped, being in the middle of large towns or congested districts, and that the best coal and water facilities will not be available.

As regards reliability of supply—an essential condition—concentration of generating capacity in large units in conjunction with a main electrical power distribution system is not a source of danger but the reverse, because by means of such an inter-connected distribution system,

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* Paper read before Sections B & G of the British Association at Newcastle, September 8, 1916.

one set of generating plant can act as spare to another, whereas, according to the present method of dealing with electricity supply by means of isolated networks, each supplied in general from one generating station, there is no duplication of generating stations or alternative ways of feeding a given area whatever.

Thus, if the community is to benefit by the electric supply industry being given the maximum chance of development, and if the erection of the most economical generating machines in the best possible positions for economical production is to be secured, and insisted upon, as it must be, by some central authority, the first thing to aim at is the establishment in each industrial district of a common inter-connected electrical power distribution system.

As has already been indicated, such an ideal may be achieved in this country, on account of its compact nature, to an extent which is not possible in other countries. What is required is co-operation and joint working between the different company and municipal electric supply undertakings, and this, except in certain cases, has not been possible in the past, due largely to Parliamentary and municipal opposition. If such a complete and unified system of mains could be established in each industrial area, the erection in the best situations of generating plant of the highest economy would naturally follow. That this has not been done in the past is not the fault of the electric power companies, and I am glad to see that many municipal undertakers are now as convinced as the power companies that this joint working is essential.

Another advantage which would follow the erection of plants on roomy and efficient sites, rather than on crowded and inefficient sites, is that this would materially facilitate the extraction of the by-products which can be obtained from the coal before it is consumed in the boiler furnace, wherever it is commercially possible to do so. This process will require large sites. Such by-products may be of as great a value to the community as the residue of fuel, for they include :—

1. Sulphate of ammonia and other products of value as manure and as raw material for manufactures.
2. Benzol and other important hydro-carbons, of value in the dye industry, for example.
3. Oils, including motor spirit.

It has been calculated that the requirements of the country in the way of manures, crude oils, oils for marine propulsion and motor spirit for road traction can all be largely supplied as by-products of our own normal coal consumption if only proper encouragement is given to the establishment of really economical electrical power distribution systems throughout the country, but it would be out of the question to carry out such schemes in large towns.

An urgent matter for settlement is the standardisation and unification as rapidly as possible of the frequency and voltage adopted for distribution purposes in neighbouring localities. Electrically this, as I have said, is as important as having all the railways of uniform gauge. It is not proposed that uniformity of frequency and voltage should be established throughout the whole country, as this would entail the scrapping of a very large amount of valuable plant, but there would be no difficulty (and considering the issues at stake, comparatively little expense) in standardising a single frequency for each of the industrial areas of the country as follows :

Midlands	25	cycles.
West of Scotland	25	,,
North-east coast	40	,,
Lancashire	50	,,
Yorkshire area	50	,,

As regards the voltage, this will require careful consideration ; on the north-east coast we have standardised 20,000 volts, and in some of the other areas 10,000 volts has been adopted, but it is a question whether this is not too low for main trunk lines.

The question is—who is to pay for this unification ? It is not, in general, the fault of the existing undertakings that they have adopted different voltages and frequencies to those in vogue in the surrounding industrial districts—though in some cases it must be admitted that it has been their desire to remain isolated, whatever the interests of the country in general and their own consumers in particular. The chief fault lies at the door of the nation itself—the Board of Trade having in the past even encouraged, in some cases, the establishment of different systems in adjacent areas.

The Board of Trade already has a right to say what system (electrical) shall be adopted as regards all new undertakings or existing undertakings developing newly acquired areas. The Local Government Board, in the case of municipal undertakings only, as loan authority, has control over expenditure on extensions of plant and mains by municipal electrical undertakings. As regards municipal undertakings which propose to adopt or extend electrical systems (plant or mains) of a type which would be inconsistent with development on uniform lines throughout the area in which they are situated, the Local Government Board could attach a condition to the loan to prevent this. The privately-owned concerns are not, of course, subject to Local Government Board control, but the powers of the Board of Trade as regards the sanction of systems to be adopted would probably be sufficient, and in any case the large power companies, who are the most important of the private concerns, operating as they do over large areas, are already fully alive to the necessity for standardisation and unification.

What is important is that a main inter-connected electrical power distribution system should be established in each industrial area as soon as possible. Just as trade between different parts of the country would be impossible or practically impossible without railways, so trade in power—that is the supply of power where most required, from the source where it can be most economically generated—is impossible without a trunk main. The electrical "roads" of the country must be standardised and made just as the railroads have been. To-day if a colliery owner has small and poor coal in his colliery which it does not pay him to bring up because it cannot stand the cost of transport, he cannot contemplate turning it into electricity at the pit mouth—extracting the by-products in doing so—because, except in certain areas where a trunk main system exists, there is no market for the electricity, there being no means of distributing or transmitting it. Each individual colliery owner cannot establish his own electrical distribution system to neighbouring towns or manufacturers any more than each manufacturer can provide his own railway system for distributing his goods. If a man has waste heat—or could, by improving his manufacturing or chemical process, combine it with the generation of power—there is no one to take his power, because the "roads" are not there to carry it ; and in most districts the large towns, where the concentrated loads already exist, are not electrically connected with adjacent industrial and colliery areas.

In the above remarks I have considered the matter chiefly from the point of view of saving fuel ; it is worthy of note, however, that inter-connected electrical power distribution systems are essential if the capital charges and labour costs, which are very important items in the production of electricity, are to be kept to a minimum. This arises from the fact that it is only by supplying all the needs of the community from one system that the maximum use can be made of the plant. As a great many individuals in a given community do the same thing at the same time, what we must take advantage of is that the individual does not and cannot do half-a-dozen things at once. The economy of the combination of all requirements, power, traction, heating and lighting is fundamental.

To show how far we are from this ideal let us take the case of London :—

LONDON ELECTRICITY SUPPLY.

Present position.

	Central Area.	Greater London.
Number of Authorities	39	70
Number of generating stations* ..	41	70
Average size of stations	7,646 K.W	5,285 KW
Average size of units	787 KW.	632 KW.
Number of types or systems of generation	31	49
Number of frequencies	8	10
Number of voltages { Generation ..	20	32
Number of voltages { Distribution	21	24
Number of methods of charging and prices	Over 50	Over 70

* In addition there are nine traction stations within the Greater London area, eight of which are within the Central area.

A man lives, say, in Hampstead ; he cooks his breakfast, if he can buy electricity sufficiently cheaply, by electricity supplied from one station ; he travels to his office by electric train supplied by electricity from another station ; his office in the City is supplied by electricity from a third station ; probably he gets his lunch at a restaurant supplied by electricity for light, &c., from a fourth station ; if he has to go out of the office and visit other people in the afternoon he travels probably by a tram supplied by a fifth station ; he may eat his dinner at night in a West End restaurant supplied from a sixth station, go to a theatre supplied from a seventh station, and so on. So that an inhabitant of London may quite well require throughout the day anything between five and ten sets of plant to supply his needs. In other words, the capital costs of supplying him are increased five or six fold.

This is a result altogether apart from the fact that, due to the enormous number of systems and stations in London, the plant used is of ridiculously small size, and therefore the efficiency as regards coal consumption is very low—in fact, the average efficiency of conversion from coal to electricity in London to-day is only a third of what it would be under any modern scheme.

What applies to London applies equally to other industrial districts if we substitute the factory for the office.

It may be well, in conclusion, to summarise the advantages and economies resulting from electrical development on correct lines :—

1. A large saving in coal as a result of the erection of plants of the most economical size, according to the load, in the best positions.
2. The utilisation of waste heat.
3. The utilisation of coals which are too friable for transport.
4. The utilisation of coals now left in the pits because their value will not stand the cost of transport, and of other combustible materials not at present used as fuel for the same or other reasons.
5. The development of new carbonisation and distillation processes.
6. The more general use of electrical energy for all purposes, *e.g.*, industrial power, rail traction, metallurgical, electro-chemical and furnace work, and the development of industries which it has hitherto not been possible to carry on in this country.
7. Increased industrial output as a result of a greater use of power in consequence of its lower cost.
8. A general improvement in the efficiency of prime movers by British manufacturers, which cannot but have a marked effect on all power-generating machinery (including that for marine purposes) and on our foreign trade. The British manufacturer can only compete with those of other countries if the things he has to sell are as good or better. In the case of the largest prime movers there are at present only two purposes for which they are used on a large scale, namely, for marine purposes and for driving electric generating plant. It is a fact that, in recent years especially, the larger prime movers have invariably been developed for land purposes first, the marine engines following, *e.g.*, the Parsons turbine and the large internal combustion engine. One reason for this is that the experimental work involved in developing new types and larger sizes of prime movers is more easily and more economically carried out ashore. Hence it is clear that the development of electric supply on right lines affords the best field for progress in design and economy.

What is fundamentally and immediately necessary is the establishment of a national electrical trunk mains distribution system.

Proceeding on these lines we shall not be merely copying America or Germany—we shall be doing something that is right for England because it is England, and because England is radically different from other countries as regards the technical development and "lay out" necessary to secure cheap power. We have delayed making a start on right lines 15 years longer than is necessary—let us delay no longer.

DOUGLAS FIR TESTED BY BRITISH RAILWAY.—We read in the *Railway and Marine News*, Seattle, that two Douglas fir and two red cedar railway ties were recently forwarded by the forest branch of the Department of Lands to the Great Eastern Railway Company of England, which selected two sleepers from its stock obtained from the Baltic and tested them all under similar conditions. The results of these tests show beyond a doubt the superiority of Douglas fir for railroad ties. It was found that under compression Douglas fir will stand 5,695 lb. per square inch, as against the Baltic timber mark of 3,950 lb. per square inch, while red cedar made a very creditable showing against the Baltic timber. Tests in tension were even more favourable for Douglas fir. This is shown by the fact that it would take 11,450 lb., or more than 5¼ tons, to pull apart a stick of Douglas fir having a cross-section of 1 sq. in., whereas just half that weight would suffice to pull apart Baltic timber, and only 3,300 lb. to separate cedar.

NORTHAMPTON POLYTECHNIC INSTITUTE, CLERKENWELL, LONDON, E.C.—In view of the continuance of the war, and the consequent absence of many students at the front or on special war or munitions service, the Governing Body of the Polytechnic has decided to suspend the usual annual issue of the announcements, but is prepared to start and carry through in the session 1916–17 as many of the courses and classes announced for the preceding session as may be justified by the applications for enrolment received at the commencement of the session. A summary of the courses and classes in "Heavy Electrical Engineering" is issued, and intending students are advised to make early application for enrolment to ensure that the courses or classes in which they are interested shall be held. If, happily, peace be declared, either before the session commences or sufficiently early in the session, the full educational activities of the Polytechnic will be resumed as quickly as possible. The evening session will commence on Monday, the 25th inst., and will continue, with the usual intervals at Christmas and Easter, until May 25, 1917. Enrolments commence on the 18th inst. Information regarding the classes can be obtained from the Principal, St. John-street, Clerkenwell, E.C.

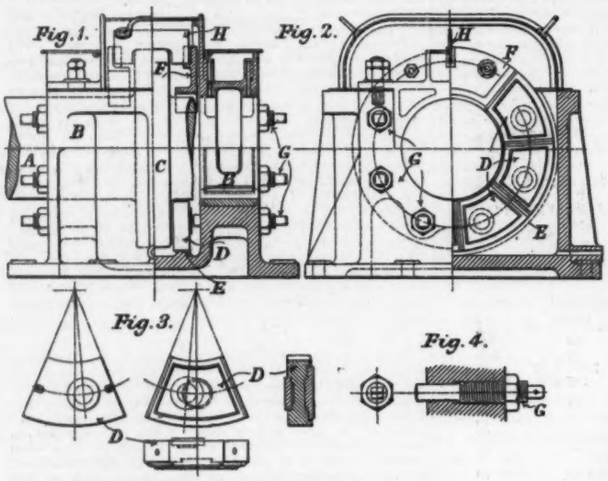
ELECTRIC LIGHTING ACTS, 1882 TO 1909.—The Board of Trade having received a considerable number of applications for consent to the erection of temporary overhead lines for the transmission of electrical energy, attention is called to the following Memorandum :—Every application for the consent of the Board of Trade to the placing of electric lines above ground should be accompanied by the following particulars : (1) Where the undertakers are a company, or a local authority supplying outside their own area, evidence of consent of the local authority for the district. (2) A statement showing commercial or other considerations why underground cables should not be used. (3) A brief description of the proposed system, whether by continuous or by alternating current ; the working voltage ; the kind of wire whether copper or aluminium, whether solid or stranded ; the total sectional area ; tensile strength and elongation ; average and maximum length of span ; minimum height of wires from the ground ; name or description of automatic protective device, if any. (4) A statement whether the supply is to form (1) an extension of an existing system of underground cables, or (2) of an existing traction system, or (3) an independent system. (5) An ordnance map on a scale of 6 in. to the mile, showing the proposed route of the overhead lines and any existing overhead lines. The sheets of these maps must not be fastened together. (6) In the case of high and extra high pressure, plans of construction of poles, &c., on a scale of about 1 in. to the foot, or a reference to previously deposited plans where these are identical with the proposed work. Notes.—Codes of Regulations have been made (1) for overhead lines for low-pressure and medium-pressure continuous-current supply, and for low-pressure alternating-current supply, and (2) for pressure exceeding low or medium-pressure continuous-current and low-pressure alternating-current. Regulations will be made for each case separately, following these codes unless special alterations are sanctioned. Attention is called to the necessity for obtaining the approval by the Postmaster General of plans and works under Section 14 of the Schedule to the Electric Lighting (Clauses) Act, 1899.

PRESSURE OIL FILM LUBRICATION.*

By H. T. NEWBIGIN, A.M.I.C.E.

THE primitive form of journal bearing is merely a hole bored in the frame of a machine in which a shaft revolves, and the primitive thrust bearing is only a collar or shoulder on a shaft to prevent it moving endways. These fulfil their function satisfactorily for many purposes, but as the rubbing speed increases, either due to an increase in the shaft diameter or an increase in the speed of its rotation, or both, it becomes necessary to devote more attention to the design of these machine parts, apart altogether from the effect of a reduction in friction on the efficiency of the machine as a whole.

Without lubrication a bearing will not run without excessive wear, and without artificial cooling no bearing with oil lubrication will run continuously if the temperature rises above 150 deg. F., because at about this temperature most oils begin to carbonise. The efficiency of a bearing must therefore be such that the temperature due to the heat generated by its friction, minus that dissipated by radiation and conduction, does not exceed this figure.



In order to reduce the friction between two rubbing surfaces it is necessary to put something between them, and bearings may be classified into those in which this is a hard material such as steel balls or rollers, or a viscous substance like oil or grease.

The first class does not consist merely in introducing balls or rollers between the relatively moving surfaces in the primitive forms of journal and thrust bearings, they are highly specialised machine parts designed to utilise to the greatest advantage the rolling action of balls or rollers in reducing friction, and their design is evolved from a study of this action. On the other hand (except in the cases to which reference will be made later) the second class consists merely in applying a lubricant to the primitive forms, or to some slight modification thereof. They are not designed to utilise the action of the lubricant on any principle, the lubricant is merely added to the primitive forms because it has been found to make them work better. Ball and roller bearings have attained to a remarkable degree of perfection, and they are admirably suited for bearings in which the loads to be carried are comparatively light, or in which the motion is intermittent, but they are not suited to carry heavy continuous loads, especially at high speeds.

In ball bearings the steel balls make point contact with hardened steel races, and the balls tend to flatten at the point of contact. Under excessive continuous loads this slight deformation of the balls causes their outer surface to shell off, the chips get under the other balls and ultimately destroy the construction of the bearing. The life of the balls is limited, frequent renewals are necessary, and to effect these renewals it is essential to dismantle the bearing.

In roller bearings the rollers make (or are supposed to make) line contact with the housing and with the shaft. Although they are able to carry heavy loads, it is very difficult to maintain correct alignment, and any slewing of the rollers sets up a heavy end thrust against the cage in which they work. Furthermore, as the rollers bear directly on the shaft, the constant rolling action tends to laminate the surface and so wear it away. In roller thrust bearings it is necessary to make the rollers conical, and as they therefore have a heavy radial thrust this type of bearing is not much used.

The great advantage of both ball and roller bearings is their low starting friction; for this reason they are especially suitable for intermittently moving machinery, but in continuously running machinery where a low starting friction is of less importance than a low running one, it is obviously a great advantage to have the rubbing surfaces separated by something more easily replaceable than either balls or rollers, especially if it is something that can be continuously replaced without stopping the machine, and the more so if it is also capable of being used in high-speed bearings as a medium for carrying away the heat generated by friction from the actual surface of its origin.

It is with the second class of bearings—those in which the surfaces are separated by a fluid such as oil in the case of high-speed and grease in the case of slow-speed bearings—that this paper is more immediately concerned. The use of a lubricant for the purpose of reducing friction is very old, but the study of its action, and more especially the manufacture of bearings designed to utilise this action to the best advantage, is quite modern.

The action of a lubricant is twofold; it first of all alters the nature of the rubbing surfaces, thereby reducing friction (and this is the commonly accepted justification for its use), but under favourable conditions it goes much further than this and automatically generates a high-pressure oil film between the surfaces, entirely eliminating metallic contact and thereby enormously reducing the friction. This is what is now called "pressure oil film lubrication." It occurs to a limited extent in most journal bearings, but does not occur in ordinary collar-thrust bearings.

The phenomenon of pressure oil film lubrication was first noticed by the late Mr. Beauchamp Tower during the course of a series of tests he made in conjunction with the Institute of Mechanical Engineers in 1883 and 1885. He found, while experimenting with a journal bearing, that under certain conditions the rotation of the shaft was capable of dragging the oil adhering to it in between the surfaces to such an extent as to force the surfaces apart with a high-pressure oil film, and that the highest pressure in this oil film was about twice the average pressure. He also found that the highest pressure was on the longitudinal centre line of the brass and a little forward of the sectional centre line in the direction of rotation, and that from this point the pressure fell to zero around the edges of the brass. A bearing under these conditions runs with very much less friction than under any other, and will carry a much higher load.

Following on Tower's experiments, the late Professor Osborne Reynolds, F.R.S., in a paper read before the Royal Society in 1886 on "The Theory of Lubrication," showed that the friction under the circumstances was merely that due to the viscous flow of the oil, and he showed how, by calculation based on the theory of viscous flow, a pressure curve may be obtained which closely approximates to that obtained experimentally by Tower.

In his theory Reynolds made the assumption that the length of the bearing, i.e., the dimension at right angles to the direction of motion, was infinite, and as this is never the case in practice, his theory was of little practical value and it did not lead to any alteration in the construction of bearings. From the practical point of view the most important things that he showed were:—

Firstly—That in order to obtain a pressure oil film between lubricated surfaces the surfaces must have a slight inclination to each other, with the opening at which the oil enters greater than that at which it leaves. Or, in other words, that the oil film must be wedge-shaped.

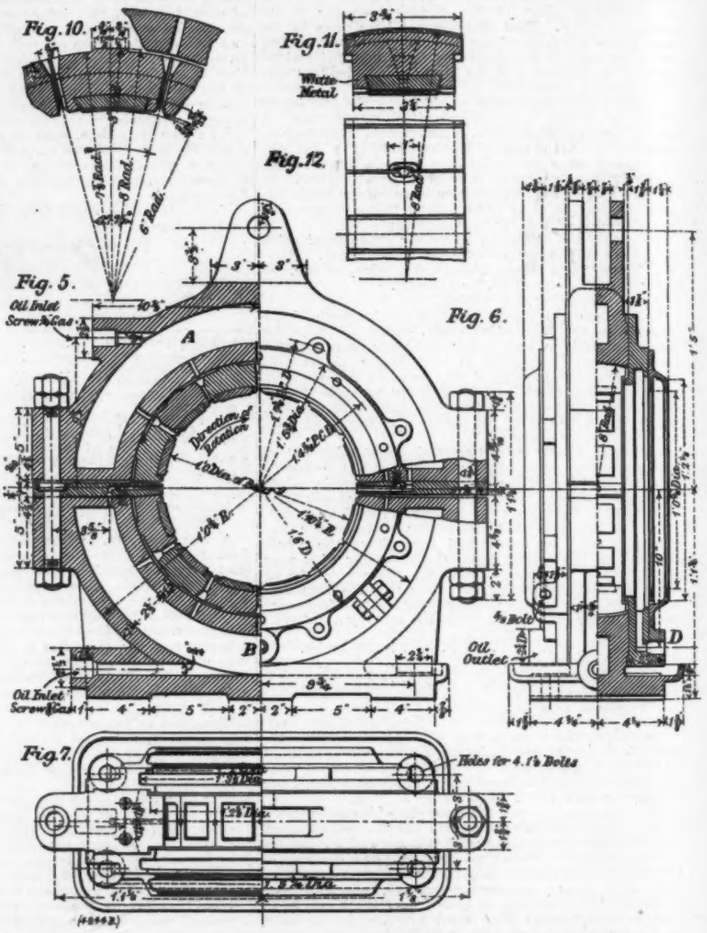
Secondly—That in the case of a journal bearing the wedge form of the oil film occurs naturally, due to a slight shifting of the centre of the shaft in relation to the centre of the brass.

Thirdly—That such a wedge-shaped oil film cannot occur in a collar-thrust bearing; hence their inefficiency and low carrying capacity.

It was left to an Australian engineer and mathematician, Mr. A. G. M. Michell, of Melbourne, not only to complete Reynolds's theory, but also to show how its teaching can be applied in practice, to the vast improvement of both thrust and journal bearings.

In a paper published in *Zeitschrift für Mathematik und Physik* (unfortunately a German publication) in 1905, on "The Lubrication of Plane Surfaces," he gave the complete mathematical solution of Reynolds's theory as applied to plane rectangular surfaces. And on the assumption that the thickness of the oil film at the entering edge is twice as great as at the leaving edge, he showed how lines of equal pressure within the film can be plotted and how the centre of resultant pressure can be determined for plane rectangular surfaces of varying proportional cross dimensions. He also demonstrated practically that a rectangular block pivoted at its point of resultant pressure will automatically assume an angle to an opposing lubricated surface, depending on the speed of rubbing, viscosity of the oil and pressure. On this principle he founded his now well-known thrust bearing.

The result of Mr. Michell's work has been to enable lubricated thrust and journal bearings to be designed with the principles of oil film lubrication as a basis, in the same way as ball and roller bearings are designed with the ball or roller as a unit, and as distinguished from the mere application of oil to the primitive forms of these bearings. The essential feature of the Michell bearings is the subdivision of the stationary surface into a number of blocks or pads, each pivoted at its back, and so free to assume a slight angle with its contacting surface. Bearings designed on this principle differ radically from the primitive forms of journal and thrust bearings, but the results obtained in practice have fully justified the change.



* Paper read before Section G of the British Association at Newcastle.

Taking the case of the thrust bearing first, the Michell thrust bearing differs from the older type in having only one collar, the multiplicity of collars in the older type having been necessitated by the low carrying capacity of parallel rubbing surfaces, as distinguished from the high carrying capacity of those in which the fixed surface is subdivided and made free to assume the angle to the opposing collar necessary for the formation of oil pressure within the film.

The importance of efficiency in machinery is not merely a question of economy of power or fuel, it also controls the practicability of a design, and the design of bearings is an example of this. For example, in the design of a large multicollar thrust bearing (which is merely an elaboration of the primitive form) the problem the designer has to solve is governed by the efficiency of this form. He has given a shaft of a certain diameter, revolving at a certain speed, and which has to withstand a certain thrust. The resistance to turning will be about 0.03 of that thrust, and the greatest load that the bearing surfaces will carry with safety is about 50 lb. per square inch.

In order to bring the pressure down to this figure, he may either use a few collars of large diameter or a number of collars of small diameter. If he does the former, he increases the radius at which the friction acts, and so the power absorbed and the heat generated, and if he does the latter it becomes increasingly difficult to maintain an equal distribution of the load among the collars, especially under the variations of expansion due to the heat generated when the bearing is at work. Furthermore, whatever compromise he makes, there comes a point beyond which the size, load and speed cannot be increased because, owing to the high coefficient of friction, the heat is generated more quickly than it can be dissipated by radiation and conduction, even with the aid of water cooling.

This point was reached in the case of the thrust bearings in geared turbine-driven vessels, and partly because the bearings were found to be less able to withstand thrust under the uniform turning movement given by this type of engine than under the varying turning movement given by reciprocating engines. It therefore became necessary to find a form of thrust bearing in which the coefficient of friction is lower than that in the primitive type.

The Michell thrust bearing, which goes to the root of the matter and is designed from the point of view of the action of the lubricant in automatically generating a pressure oil film between the surfaces, has formed a complete solution of the difficulty. It has a coefficient of friction of about 0.0015 as against 0.03, and carries 200–300 lb. per square inch with a much greater factor of safety than the primitive form has at 50 lb.

The subdivision of the fixed surfaces into a number of segmental tipping blocks or pads is the essential feature of all thrust bearings made on this principle, but there are many variations in the design of the housing and method of carrying the tipping blocks, depending on the particular use to which the bearing is to be put.

Figs. 1 and 2 show sectional side and end views of one form in which marine thrust blocks are made.

The shaft "A" is supported in two journal bearings "B," one on each side of a single collar "C," which bears against two series of segmental pivoted blocks "D," arranged in the form of two inverted horse-shoes, the one for "ahead" and the other for "astern" thrust.

The blocks "D"—each of which is pivoted, somewhat behind its centre, on the ends of the screws "G"—rest on two ledges "E," concentric with the shaft. They are prevented from rotating with the shaft by means of the stops "F," by removing which they may be taken out without disturbing the adjustment of the screws "G" or lifting the shaft. Figs. 3 and 4 show a detail of one of the blocks "D," and of its screw "G."

The body of the housing forms an oil well in which the collar revolves, and a scraper "H" is provided to scrape off the oil brought up by the rotating collar for the purpose of lubricating the upper blocks.

This type is self-contained as regards lubrication, and in the case of large sizes, or those running at a high speed, the body of the bearing is water-jacketed. The friction is about one twenty-fifth of that in the multi-collar type.

In the case of the thrust bearings in steam turbines the type adopted is somewhat different. The blocks are symmetrically disposed around the faces of the collar, and each series is mounted on a ring partly spherical on one face, the convex surfaces of which are outward and rest on correspondingly spherical seats for the purpose of automatically distributing the load among the blocks. The blocks are mounted on the faces of the rings next the two sides of the collar against which they pivot, either along radial lines or on rounded pins.

This type is entirely enclosed, and is supplied with an oil circulation by means of an independent pump. The oil passes through an oil cooler on its course, thereby removing the heat generated by friction from the actual surface of its origin. The mean rubbing speed sometimes exceeds 100 ft. per second. Slow speed bearings are made on the same principle, with grease lubrication.

Upwards of 800 Michell thrust bearings are now running in this country alone, in sizes varying from 1 to 15 in. diameter of shaft, and larger sizes are in the course of construction. The use of them is rapidly becoming the standard practice in steam turbine work. The same principle is now being applied to journal bearings.

In lubricated journal bearings of the primitive type (as already stated) the phenomenon of pressure oil film lubrication occurs naturally, due to the slight shifting of the centre of the shaft in relation to the centre of the brass, but its occurrence is much less marked in the case of bearings of large diameters, probably owing to the greater oil clearance that is necessary in large sizes and to the extreme thinness of the oil film. For example, a journal bearing of 2 or 3 in. in diameter will run satisfactorily under a pressure of 300 to 400 lb. pressure per square inch, but it is not found advisable to load large bearings above 100 lb. even with a forced oil circulation.

The pressure oil film only occurs along a narrow strip in the primitive type, and the remaining surface merely forms a brake on the rotation of the shaft. So that the designer is again restricted and can only reduce the pressure to the limit found safe in practice by increasing the length of the bearing. But by subdividing the circumferential surface into a number of segments, each of which is pivoted at its back and thereby free to form an independent pressure oil film between its rubbing surface and the shaft, the number of the pressure oil films can be increased, so that the full projected surface of the bearings becomes effective for carrying load, and the brake surface is eliminated. The friction is thus reduced, the load-carrying capacity increased, and the bearing shortened.

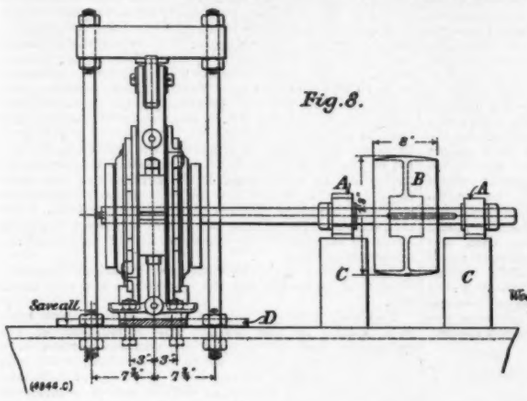
A series of tests has recently been run on a Michell journal bearing by Messrs. Cammell, Laird and Co., Limited, Birkenhead. Figs. 5, 6 and 7 show details of the experimental bearing, and Figs. 8 and 9 the method of testing it.

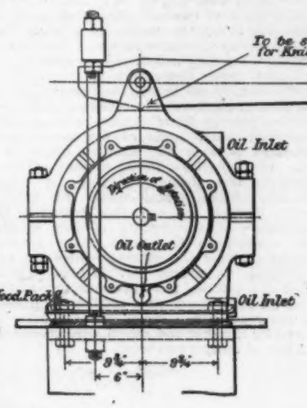
As will be seen from Fig. 5, the bearing surface is divided into 12 segments, each of which is pivoted on a rib at its back, so that it is free to lift at its leading edge to allow the necessary wedge-shaped oil film to form. These segments are shown in detail by Figs. 10 and 11.

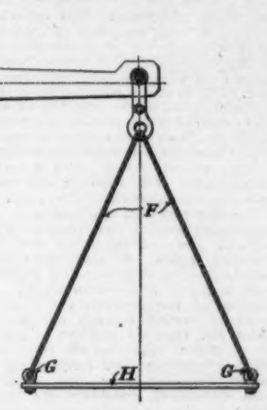
The faces of the segments or blocks are lined with white metal, each surface being 2 in. square, giving 48 sq. in. of rubbing surface, the equivalent projected area of each half of the bearing 16½ sq. in.

In addition to the segments being free to tilt, the seat on which they rest is partly spherical, thereby making the bearing also a swivelling one. A circulation of oil was passed through the bearing, entering it between each pair of blocks from the chambers "A" and "B," and escaping at "D." The bearing was driven by means of an electric motor, and the ammeter and voltmeter readings recorded. Each run was continued until the oil temperature ceased to rise. The ingoing and outgoing temperatures of the oil were also recorded, together with the weight of the oil passing, and the revolutions per minute. The load was applied by adding weights and the scale pan "H," shown in Fig. 9, the leverage being 11 to 1.

The annexed Table gives the results observed, together with the friction calculated from the heat taken up by the oil. The friction is that for the two halves of the bearing pressed together. To get the coefficient of friction these figures require to be divided by twice the load.







TEST OF EXPERIMENTAL "MICHELL" JOURNAL BEARING. MAY, 1916.

Date and Duration of Test.		Total Load.	Bearing Pressure.	Revs. per Min.	Surface Speed.	Amperes.	Volts.	Horse-Power Input.	Oil Supply.				Friction Horse-Power from Heat to Oil.	Coefficient of Friction.	Actual Friction.
									Final Inlet Temp. F.	Final Outlet Temp. F.	Rise of Temp. F.	Flow of Oil.			
May.	Mins.	Lb.	Lb. per sq. in.		Ft., Min.				Deg.	Deg.	Deg.	Lb., Min.			Lb.
18	45	—	—	585	1,840	16.5	406	9.2	68	84	16	12.6	1.9	—	—
18	105	2,400	145	620	1,950	14.5	403	7.9	79	99	20	14.8	2.8	0.0099	47.5
18	105	3,600	220	615	1,930	16.0	395	8.6	84	101	17	14.3	2.3	0.0054	39.2
19	60	4,800	290	605	1,900	16.6	382	8.6	83	100	17	15.6	2.5	0.0045	43.7
19	40	6,000	370	615	1,930	16.9	395	9.1	84	102	18	17.6	3.0	0.0043	51.6
19	75	7,300	440	607	1,907	18.9	391	10.0	84	102	18	18.7	3.2	0.0038	55.4
19	45	8,500	520	605	1,900	19.0	395	10.2	83	99	16	19.0	2.9	0.0029	50.1
19	60	9,800	600	618	1,940	20.4	395	10.9	71	93	22	19.0	4.0	0.0034	67.6
20	90	11,700	700	611	1,920	21.0	391	11.1	76	100	24	19.7	4.5	0.0033	77.2
20	30	14,800	900	620	1,950	26.5	400	14.4	77	102	25	22.7	5.4	0.0031	91.7
24	30	—	—	1,315	4,130	23.0	390	12.2	76	95	19	23.0	4.1	—	—
24	60	2,400	145	1,320	4,140	27.8	392	14.8	74	96	22	26.4	5.5	0.0091	43.7
24	45	5,500	330	1,320	4,140	29.8	390	15.8	77	104	27	25.2	6.4	0.0046	51.1
24	60	8,500	520	1,303	4,100	40.0	398	21.6	82	117	35	33.0	10.9	0.0051	87.5
25	60	11,700	700	1,324	4,140	50.0	382	26.0	76	111	35	37.3	12.2	0.0042	98.3
25	105	11,700	700	1,317	4,140	42.0	390	21.2	73	112	39	31.2	11.5	0.0039	91.2
25	30	14,800	900	1,320	4,140	45.5	400	24.7	76	117	41	33.0	12.7	0.0034	100.4

AMERICAN CIVIL ENGINEERS' POCKET BOOK.—American engineering pocket books have a well-deserved reputation for comprehensiveness of matter and simplicity of statement. This is well maintained in the third edition of the American Civil Engineers' Pocket Book just issued by Messrs. John Wiley and Sons, and to be obtained in this country from Messrs. Chapman and Hall, Limited, price 21*s.* net. We reviewed this work at length on its first appearance and need not repeat our former verdict. The new matter includes a section, 96 pages long, on harbour and river work. In all, this third edition has been increased by 41 new articles, 31 tables and 103 new illustrations. The field covered by the book is very wide, and each section has been entrusted to the editorship of a specialist in that particular class of work, but care has been taken not to write as a specialist for specialists, but to make the text as simple and complete as possible. A most valuable feature in the work is the numerous tables showing the actual or approximate costs of different engineering operations. We note one error requiring correction. The formula given for the stress on loaded hooks, on page 314, is very erroneous, being based on the assumption that the bending stress varies (as in the case of a straight beam) according to a straight-line law. Actually the law of stress variation may, for a curved beam, be taken as hyperbolic, and the maximum stress is very much more than the formula criticised indicates.

THE PRINCIPLE OF SIMILITUDE IN ENGINEERING DESIGN.

By T. E. STANTON.*

In preparing the present paper, which, at the suggestion of the Committee of Section G, has for its subject the Principle of Similitude, it seemed to the writer that it would be meeting the wishes of the majority of the audience if the paper were mainly devoted to illustrations of the usefulness of the principle in solving practical engineering problems rather than to any formal demonstration of it, for which reference may be made to the literature of the subject.† As a broad definition it may be said that the principle of similitude is the principle according to which a representation of any particular mechanical phenomenon can be made so that the magnitudes of all characteristics of the same kind are changed in the same ratio, or, in other words, there is a definite change of scale for each characteristic. Of course, since each characteristic can be expressed in terms of the fundamental units such as those of mass, length and time, it is ultimately only the scales of these units which are altered, and it follows from the principle that these scales cannot in general be changed arbitrarily, but only according to a definite relation determined by the principle. Now, there is one case of such representation which is familiar to every engineer, and that is when the only characteristic which is changed is the linear dimension. This case includes the whole subject of scale drawings of machines and structures and the construction of models, and the study of it forms an important part of the education of every engineer. Apart from this particular application, it can be assumed that, as far as the problems of the engineer are concerned, the application of the principle of similitude means in nine cases out of ten nothing more than the laying down of the conditions of an experiment on a small-scale model of any mechanical arrangement which we wish to design, so that we can predict with accuracy any particular characteristic of it from an observation of the corresponding characteristic of the model.

The first practical application of the principle to an engineering problem was, I believe, Mr. William Froude's method, proposed in 1870,‡ and carried out in the following years, of obtaining the "wave-making" resistance of a ship from an experiment on a small-scale model of it towed in water. A general demonstration of the conditions for similarity of motion in water flowing through orifices under gravity, to which Mr. Froude's problem is analogous, was given in a paper read before this Association at the Glasgow meeting just forty years ago by Professor James Thomson. In this paper it was proved from dynamical considerations that in the flow of water relative to similar and similarly situated orifices similarity of motion in corresponding stream-lines would only take place if the linear dimensions of the orifices were proportional to the squares of the corresponding velocities of dow and that when this condition was fulfilled the discharge would be strictly proportional to the $\frac{5}{2}$ power of the linear dimensions of the orifices or weirs. James Thomson's method of demonstration was, however, somewhat complicated for general application, and others have since been developed, of which the simplest and most readily applied is probably the well-known one due to Lord Rayleigh.§

Another method and illustrations of its application to several of the problems discussed in the present paper has recently been given by Mr. Edgar Buckingham in a paper on "Model Experiments" read before the American Society of Mechanical Engineers in 1915.

The method now adopted is to write down a list of all the variable characteristics which can affect the value of the particular characteristic which we wish to determine, and applying the principle of similitude we obtain a relation which must exist between certain other characteristics in the model and the full-sized test in order that the observed value of the particular characteristic for the model may be comparable (*i.e.*, in a known ratio) to the corresponding one in the full-sized test. This qualifying relation is called the Law of Comparison.

It would appear, therefore, that the use of the principle of similitude by engineers is essentially a modern device, for if one glances back over the history of the design of structures from the earliest times, we shall, I think, find no definite evidence that small-scale experiments were made use of for the purpose of design up till, say, fifty years ago. The principles according to which the proportions of the great works of architecture of past ages were evolved have always proved a fascinating subject of study, although in the opinion of our architectural friends it is one upon which no engineer should have the presumption to offer an opinion. If these proportions were entirely settled by æsthetic considerations this attitude might be accepted by engineers, but it is obvious that in some of the mediæval works considerations of equilibrium and of the strength of materials are of first-rate importance, and it is with such cases that the engineer is concerned. As regards the methods of design, it was the opinion of the late Professor Rankine that the great works of antiquity evinced a profound study of the principles of equilibrium. This statement will, I think, be generally accepted if one interpret it as meaning that the study consisted of close attention to the behaviour under natural forces of such combinations of masonry as the æsthetic instincts of the designers suggested. Again, of the testing of materials as we understand it, presumably nothing was known in mediæval times, but we may be certain that the early designers had a good working knowledge of the limiting stresses of their materials which was the result of accumulated experience of past failures of full-sized structures. I am informed by an authority on the subject that in the Gothic cathedrals of England the way can be distinctly traced in which during some hundreds of years successive designs were æsthetically improved by continuous refining in lightness of construction until a stage is reached when it would seem that the necessary courage to carry out the design failed the constructors. Doubtless there would be cases also in which the necessary courage to build was found and it was the structure which failed, but unfortunately these episodes are apt to be left unrecorded. In short, improvement in constructional design in past ages would appear to have been almost entirely due to an application of what in later days has come to be known as "The Squeers Method," but with this limitation, that the observations were all made on the full-sized structure. I think, therefore, one may fairly conclude that scale-model testing is essentially a modern invention. It would not, however, be fair to the early pioneers in this subject to attribute the neglect of an appreciation of the information given by a scale-model test to a failure to realise its merits. Their problems nearly always dealt with the behaviour of structures which, when they failed, failed under their own weight, and not under the action of external forces, and in such cases, as we know, the force of gravity varies as the cube of the linear dimensions and the area of support as the square. It follows that a small scale-model of a structure, when made of the same material as the structure, is essentially stronger under its own weight than the structure itself, so that without the knowledge of the ultimate strength of materials which we now possess, a scale-model test would be worthless. Possibly it was this inherited and acquired knowledge of the futility of any small-scale model test applied to structures under gravity that was accountable for the general reluctance, amongst naval architects, to accept Mr. William Froude's suggestions of predicting the wave-making resistance of a ship from an experiment on a small-scale model of it towed in water at such a speed that the wave patterns produced by the ship and model were geometrically similar, the law of comparison being

$$\frac{g\,l_1}{v_1^2} = \frac{g\,l_2}{v_2^2}$$

under which conditions the ratio of the resistances would be

$$\frac{R_1}{R_2} = \frac{\rho_1\,l_1^3}{\rho_2\,l_2^3}$$

where l, ρ and v are the linear dimensions, density and velocity of the fluid respectively (case 5 of table appended).

Fortunately Mr. Froude had the support of the Board of Admiralty at the time, and was enabled to carry out his proposed experiments, with the result, as we all know, that his method of small-scale model tests is now universally adopted as the only reliable method of the determination of the resistance of a ship of given proportions, except, of course, the heroic one of testing the full-sized ship.

This, I believe, was the first application of the principle of similitude to the purpose of obtaining the data for the design of structures. No further extension of its use has taken place until comparatively recently, when it has been realised that it could also be employed to obtain some of the necessary data required in the design of aircraft, although in this case, as we shall see later, there is a practical limitation which does not trouble the designer of ships.

From this glance at the extent to which the principle of similitude is used by designers of structures, the conclusion may follow that the sole value of small-scale model experiments is for the determination of the fluid resistances of bodies moving in air or water. Admitting that these applications of the method are the most important, it by no means follows that they are the only useful ones. For example, although the use of tests of small-scale models of statically loaded structures and their details has not hitherto formed part of the routine in laboratories for testing materials, it is probable that, in many cases, such tests would give more valuable and more reliable results than the attempts we often see to apply the simplified elastic theory to problems for which it was never intended. Thus, in calculations on the stress distribution in beams, we are accustomed to make certain assumptions as to the manner in which the elastic deformation takes place, which enable us to apply the mathematical theory of elasticity and obtain results without the expenditure of great labour. In the majority of cases these results are sufficiently accurate for our purpose, but one is continually coming across cases in which they may lead to quite incorrect conclusions. The writer has often been impressed by the apparent horror with which the rigid elastician is accustomed to regard the recklessness with which the engineer will attack some extremely complicated case of stress distribution by means of the simple beam formula. In such cases it will often be found that a small-scale model test will offer the best solution of the problem, and the first illustration which I propose to give of the use of the principle of similitude deals with its application to statically loaded structures.

To the foregoing remarks it may be objected that if the application of the principle of similitude to problems of design means in general the making of small-scale model tests, then this principle is already in universal use in our testing laboratories, since the whole practice of testing materials involves the assumption that the resistance of any member of a structure can be predicted from that of a small specimen of the same material by making a test to destruction of it and assuming that the relative resistances in the two cases vary as the sectional area. Closer examination will show, however, that this practice means nothing more than a recognition of the fact that, as far as the resistance of members in direct tension are concerned, geometrical similarity can be ignored, *i.e.*, the limiting load may be taken as proportional to the area and independent of the contour of the section. It is now coming to be recognised that this assumption is not correct; that in the case of cast iron and the harder steels a sudden change in section will cause failure at lower values of the load per unit area than when the change of section is very gradual. Further, it is well known that the real use of the results obtained in a testing machine from tests to destruction of small specimens of the material from which large structures are to be made is to determine whether the characteristics of the material attain certain recognised standards of performance under this kind of test. Now these standards are not only standards of resistance, but of permanent deformation, and in this latter case it is known that to obtain the same standard from specimens of the same material, these must be geometrically similar if they are not all of the same dimensions. This fact has now been recognised for some years by the Engineering Standards Committee in their specification for test pieces. In this sense, then, it may be admitted that scale-model testing is in use in our testing laboratories, and the question arises: Can its use be extendep so as to be capable of application to scale models of the structures themselves? Obviously from the considerations already pointed out, if the weight of the structure itself is an important factor in the total loading, it is of little practical value, as shown by the conditions (1) and (3) of the table appended. If, however, the weight be negligible, an application of the principle of similitude (case 2 of table) shows that for geometrically similar and similarly loaded structures of the same material, if the stresses at corresponding points are the same, the loads must be respectively proportional to the square of the linear dimensions.

Careful tests of similar structures of various kinds will show that under this law the comparison is a very exact one.

I exhibit now two sets of model struts which have been tested in this way. The calculation of the collapsing load of a strut of uniform section is a very simple matter, but when, for instance, it is made taper as in modern biplanes, for the sake of lightness, the calculation is somewhat tedious, and if facilities for making a scale-model test exist, I think it is probable that by such a test a more accurate prediction of the resistance of the full-sized strut would be made than by the use of the ordinary methods of calculation.

In such tests it is, of course, of the utmost importance that the end constraints should be practically zero, and considerable care was taken to ensure this condition. The results showed that in both sets the collapsing loads were almost exactly proportional to the squares of the linear dimensions.

The actual values obtained were:—

	Maximum load.
For the $\frac{1}{2}$ size model	740 lbs.
	750 "
" $\frac{1}{4}$ "	172 "
	196 "

Another illustration of the application of the principle of similitude to structures, which has been pointed out by Lord Rayleigh,* is in the determination of the stresses set up by the impact of geometrically similar systems under the condition that the elastic limit of the material is nowhere exceeded. For greater generality we may take the case in which the densities of the systems are not the same. Assuming that the stress is dependent only on the linear dimensions, density, elasticity, and velocity of striking, the application of the principle shows (case 4 of table) that the law of comparison is

$$\frac{\rho_1\,v_1^2}{\rho_2\,v_2^2} = \frac{E_1}{E_2},$$

where ρ, v and E are the density, velocity of striking, and modulus of elasticity respectively, and that under these conditions the ratio of the stresses is

$$\frac{f_1}{f_2} = \frac{\rho_1\,v_1^2}{\rho_2\,v_2^2}.$$

The interesting facts here brought out are that the stress ratio is independent of the linear dimensions of the colliding bodies, and that for systems of the same material equality of stress is determined entirely by equality of striking velocity. This was first pointed out by Osborne Reynolds in 1873 in a paper on the sand blast,† in which he showed that the stress produced on the surface of glass subject to a sand blast was independent of the size of the particles. A consequence of this law which may appeal more to the present audience is that the elastic limit of an armour plate will be reached by any size of similar projectile having the same velocity of striking.

If we pass from this relatively simple case of impact to one in which the stresses are such as to cause fracture of one of the colliding bodies, as in the modern method of testing notched specimens, the law of comparison becomes complicated, and although considerable attention has been devoted to the subject by M. Charpy and others, as far as the writer is aware no definite means of comparing the results of impact tests on geometrically

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* Paper read before Section G of the British Association at Newcastle-on-Tyne, September 7, 1916.

† Newton, *Principia*, Book II, Proposition 32. Stokes, *Mathematical and Physical Papers*, vol. 3, page 17. Helmholtz, *Wissenschaftliche Abhandlungen*, vol. 1, page 158. Rayleigh, *Phil. Mag.*, vol. 48, page 321; *Scientific Papers*, vol. 4, page 416.

‡ Trans. Inst. Naval Architects, 1870, page 89.

§ *Phil. Mag.*, vol. 48, page 321.

* *Nature*, April 23, 1914.

† *Phil. Mag.*, vol. 46, page 337.

similar specimens under impact has yet been evolved. The form of specimen which has been standardised by the International Association of Testing Materials is one 30 × 30 mm. in section with a notch 15 mm. deep and supported on knife edges 120 mm. apart. Of course in many investigations a specimen of this size cannot be obtained, and in this case a geometrically similar specimen to one-third scale is substituted for the standard one. Unfortunately it is found that the results of tests on these two sizes of specimen are not in agreement, even if the geometrical similarity be extended to the dimensions of knife edges and striking hammer. Thus for mild steel it will be found that the energy absorbed in fracture per unit volume is from 50 to 60 per cent. greater in the small specimen than in the large one. This is for the same velocity of striking, and it would appear, therefore, as if there were some speed effect which affected the deformation of the specimens. A research on this subject has been commenced at the National Physical Laboratory, and definite evidence of the existence of a velocity effect on the work of rupture has been obtained, but it is evident that the determination of the comparison conditions will not be an easy task.

The case of scale-model experiments to determine the value of the resistance experienced by solids moving through fluids in which they are wholly or partially immersed may now be considered. The most important, or at any rate the best known, of these tests is Mr. Froude's method of obtaining an estimate of the wave-making resistance of ships, to which reference has already been made. The practical application of this method involves, of course, the separation of the resistance due to skin friction and eddy-making from that due to wave-making, since these do not follow the same law of variation with speed; and the obvious method of attacking the problem of the total resistance of a ship would be to discover, if possible, the law of comparison for surface friction and eddy-making and make another scale-model experiment for the determination of this second constituent of the resistance. It is a little remarkable that this law of comparison was discovered by Osborne Reynolds in Manchester at about the same time as the Froude Law of Comparison was enunciated by Mr. Froude. That no mention appears to have been made of it at the time may be either because the discoverer was too much concerned about the philosophical aspect of his work or, more probably, because he realised that the practical application of his law was out of the question, for the prediction of ship resistance at any rate.

The full statement of this law of comparison (case 6 of table) is, that in all cases in which the forces on a body moving in a fluid arise from the viscosity of the uid, *i.e.*, the body is so completely submerged as not to set up surface waves, then provided the condition

$$\frac{v_1 l_1}{\nu_1} = \frac{v_2 l_2}{\nu_2}$$

is fulfilled, where v, l and ν are the velocity, linear dimensions, and kinematical viscosity of the fluid, the ratio of the resistances is given by

$$\frac{R_1}{R_2} = \frac{\rho_1 l_1^2 v_1^2}{\rho_2 l_2^2 v_2^2}.$$

This is the basis of all predictions of the resistance of aircraft and submarines from experiments on scale models in air or water channels. As regards its practical value in solving engineering problems, it will be seen at once that the difficulties in its application are enormously greater than in the case of the Froude Law of Comparison. In the latter case the model speeds are considerably lower than the ship speeds, whereas in the former the speeds are so great that for small-scale model experiments *in the same fluid* as that in which the structure moves the difficulties are insuperable. Thus if R and r are the total resistances of structure and model, we have

$$\frac{R}{r} = \frac{V^2 L^2}{v^2 l^2},$$

and since $v\,l = V\,L$, $R = r$. In the case of Mr. Froude's model of the Greyhound this would mean, if the experiment were made in water, a model speed of 320 ft. per second and a pull on the dynamometer of 9,000 lb. It is, of course, not necessary that the two uids should be the same, and if we could find a fluid whose ν is very much less than that of sea water the corresponding speed of the model would be proportionately less. Unfortunately, such a fluid has not been discovered, and there is not much hope that it will be. In the case of aircraft the difficulties are very appreciably reduced. Suppose, for example, that we are designing a dirigible balloon to move at 20 ft. per second, and wish to find its resistance from a model of 1/20th scale. In air the corresponding speed of the model would be 400 ft. per second, and impossible to realise. If, however, we put the model in water, then since water has only 1/13th of the kinematical viscosity of air, the speed would be 30 ft. per second, and comes into the region of possibility. This is a very high speed for a water tank experiment, but if we were to heat the water to 80 deg. C. we could reduce its viscosity by one-half and so bring the speed down to 15 ft. per second.

It is not always realised that a determination of the complete resistance of a ship from a single experiment on a towed model could be made if a fluid of sufficiently low viscosity could be obtained in large quantities very cheaply. For example, the combination of the two sets of conditions

$$\frac{g\,l_1}{v_1^2} = \frac{g\,l_2}{v_2^2} \qquad \frac{v_1 l_1}{\nu_1} = \frac{v_2 l_2}{\nu_2}$$

leads to

$$\frac{v_1^5}{v_2^5} = \frac{l_1^3}{l_2^3} = \frac{\nu_1}{\nu_2} \quad \text{(Case 7 of table).}$$

If, therefore, a fluid of, say 1/64th of the viscosity of water could be produced, all that would be required to predict the complete resistance of a ship at 12 knots would be to tow a 1/16th scale model of it at 3 knots in the fluid of low viscosity, and the total resistance of the ship would be 4,096 times the observed resistance of the model.

It is, of course, the impossibility of finding such a fluid which necessitates the laborious and less accurate method of naval architects, which is, in the first place, to determine the wave-making resistance of the model by subtracting from its total resistance a value for its surface friction and eddy-making resistance which is calculated from experiments on thin plates towed in water. The value of the wave-making resistance of the ship is then calculated from the above reduction, and to this is added another value of the surface friction and eddy-making resistance of the ship, also calculated from plate experiments. Now, although the error in applying the results of plate experiments to the case of a ship's hull is certainly not a very large one, there is no doubt that this determination of skin friction is not nearly so accurate as the determination of the wave-making resistance. The reason is that the motion of the water round the hull is not similar to that relative to a plank, as may be seen by examination of the stream-lines by the colour method. In the case of ships with fine lines, the breadth of the eddying belt at the stern is small, but as the lines become fuller the stream-lines tend to break away and leave a comparatively large eddying region at the stern. If the extent of this region remained constant for a particular form of hull, a correction could be made for it, but it is known that it depends upon the speed, and, therefore, the surface exposed to skin friction is not the same for all speeds. It will be realised that the greatest possible care is required in making the calculations of skin friction with the existing methods.

ratio to the velocity of sound in air becomes appreciable. Recent experiments, however, appear to show that even at these speeds the effect can be neglected, and therefore since in this case there is no necessity for the observance of Froude's law, the assumption is now generally made that in air experiments the only condition for comparison is constancy of slip.

Resistance of projectiles.—In considering the case of projectiles, the compressibility of the air becomes the most important factor in the comparison owing to the fact that energy is being continually drained away in compression waves at the front and rear of the projectile.

The law of comparison will, therefore, be (case 9 of table):—

$$\frac{v_1 l_1}{\nu_1} = \frac{v_2 l_2}{\nu_2} \qquad \frac{v_1}{V_1} = \frac{v_2}{V_2}$$

and under these conditions the ratio of the resistances will be

$$\frac{R_1}{R_2} = \frac{\rho_1 l_1^2 v_1^2}{\rho_2 l_2^2 v_2^2}$$

Here, again, if the same fluid is used for both experiments—*i.e.*, $\nu_1 = \nu_2$ and $V_1 = V_2$—no small scale-model experiment is possible. If the viscosity effect be neglected as relatively unimportant, an assumption which appears to be justified, the law of comparison becomes that of equality of muzzle velocities.

It is of interest to note that the change of medium for the model experiment from air to water which was found to be helpful in the case of models of aircraft presents much greater practical difficulties for projectiles. Thus, if we carry out the model experiment on the model projectile in water, since the velocity of sound in water is about four times that in air, the speed of the model in water would have to be four times that of the full-sized projectile, or, say, 9,000 ft. per second. The comparison condition would then give a value of

TABLE.—CONDITIONS OF SCALE-MODEL EXPERIMENTS AND COMPARISON OF RESULTS.

—	Conditions.		Comparison
(1) Structure under own weight	Geometrical Similarity.	$\frac{E_1}{l_1\,\rho_1} = \frac{E_2}{l_2\,\rho_2}$	$\frac{f_1}{f_2} = \frac{\rho_1 l_1}{\rho_2 l_2}$
(2) Structure under external load only	,,	$\frac{E_1 l_1^3}{W_1} = \frac{E_2 l_2^3}{W_2}$	$\frac{f_1}{f_2} = \frac{W_1 l_2^3}{W_2 l_1^3}$
(3) Structure under own weight and external loads	,,	$\frac{W_1}{\rho_1 l_1^3} = \frac{W_2}{\rho_2 l_2^3}$, $\frac{E_1 l_1^2}{W_1} = \frac{E_2 l_2^2}{W_2}$	$\frac{f_1}{f_2} = \frac{\rho_1 l_1}{\rho_2 l_2}$
(4) Impact stresses within the elastic limit	,,	$\frac{\rho_1 v_1^2}{\rho_2 v_2^2} = \frac{E_1}{E_2}$	$\frac{f_1}{f_2} = \frac{\rho_1 v_1^2}{\rho_2 v_2^2}$
(5) Wave-making	,,	$\frac{g\,l_1}{v_1^2} = \frac{g\,l_2}{v_2^2}$	$\frac{R_1}{R_2} = \frac{\rho_1 l_1^2}{\rho_2 l_2^2}$
(6) Surface friction	,,	$\frac{v_1 l_1}{\nu_1} = \frac{v_2 l_2}{\nu_2}$	$\frac{R_1}{R_2} = \frac{\rho_1 l_1^2 v_1^2}{\rho_2 l_2^2 v_2^2}$
(7) Total resistance of ship	,,	$\frac{v_1^2}{v_2^2} = \left(\frac{l_1}{l_2}\right)^{\frac{1}{2}} = \frac{v_1}{v_2}$	$\frac{R_1}{R_2} = \frac{\rho_1 l_1^2}{\rho_2 l_2^2}$
(8) Thrust of propeller	,,	$\frac{g\,l_1}{v_1^2} = \frac{g\,l_2}{v_2^2}$, $\frac{v_1 l_1}{\nu_1} = \frac{v_2 l_2}{\nu_2}$, $\frac{v_1 l_1}{\nu_1} = \frac{v_2 l_2}{\nu_2}$	$\frac{T_1}{T_2} = \frac{\rho_1 l_1^2 v_1^2}{\rho_2 l_2^2 v_2^2}$
(9) Resistance of projectile	,,	$\frac{v_1 l_1}{\nu_1} = \frac{v_2 l_2}{\nu_2}$, $\frac{v_1}{V_1} = \frac{v_2}{V_2}$	$\frac{R_1}{R_2} = \frac{\rho_1 l_1^2 v_1^2}{\rho_2 l_2^2 v_2^2}$
(10) Heat transmission from hot surfaces to fluids flowing over them	,,	$\frac{R_1}{\rho_1 v_1^2 l_1^2} = \frac{R_2}{\rho_2 v_2^2 l_2^2} = \frac{k_1}{l_1 v_1 \rho_1 \sigma_1} = \frac{k_2}{l_2 v_2 \rho_2 \sigma_2}$	$\frac{H_1}{H_2} = \frac{l_1^2 v_1 \rho_1 \sigma_1 \theta_1}{l_2^2 v_2 \rho_2 \sigma_2 \theta_2}$

l = Linear dimension. v = Velocity. ρ = Density. ν = Kinematical viscosity. H = Thermal conductivity. σ = Specific heat. θ = Temperature difference. f = Stress. R = Total resistance. V = Velocity of sound. W = External load. E = Modulus of elasticity.

Thrust of propeller.—Another interesting example of the application of the principle of similitude is in the prediction of propeller thrusts from experiments on scale models of them in water or air. In this case it will be necessary to consider the effect of size (l), revolutions (n), speed of advance (v), and the density (ρ), viscosity (ν), and elasticity of the fluid, and also in the case of water propellers, since the immersion is not generally so great as to prevent surface disturbance, the effect of gravity.

Applying the principle of similitude, it is found that the law of comparison is a complicated one (case 8 of table) and involves four conditions, *i.e.*,

$$\frac{n_1 l_1}{v_1} = \frac{n_2 l_2}{v_2} \qquad \frac{v_1 l_1}{\nu_1} = \frac{v_2 l_2}{\nu_2}$$

$$\frac{g\,l_1}{v_1^2} = \frac{g\,l_2}{v_2^2} \qquad \frac{v_1}{V_1} = \frac{v_2}{V_2}$$

(where V is the velocity of sound in the fluid), and if these conditions are fulfilled, the ratio of the thrusts is

$$\frac{T_1}{T_2} = \frac{\rho_1 l_1^3}{\rho_2 l_2^3}.$$

It is obvious at once that if only one fluid is available the conditions can only be fulfilled if $l_1 = l_2$, which appears to preclude any possibility of a small-scale model test. On consideration, however, it will be seen that the conditions are not all essential in practice, and that some of them can be violated without risk of appreciable error. In the first place, for water propellers, the ratio of the speed of the propeller blade tips to the velocity of sound in water is so small that no effect of elasticity of the water need be apprehended. Further, since the motion of the water round the blades is extremely turbulent, it is probable that the viscosity effect is negligible. The remaining two conditions can be satisfied, *i.e.*, the slips are made the same and the speeds regulated according to Froude's Law of Comparison.

For aerial propellers the velocity of the tips may amount to from 300 to 400 ft. per second, so that its

the linear dimension of ½ × 1/13 l, or ½ in. diameter for a 13-in. shell.

Heat transmission.—The last illustration will be that of the application of the principle of similitude to problems in heat transmission from heated metal surfaces to fluids flowing over them. This is of special interest at the present time, since it bears on researches on the possibility of increasing the speed of aeroplanes by the use of air-cooling of petrol engine cylinders instead of the ordinary method of water cooling. As regards convection of heat, the theory was laid down by Osborne Reynolds that from the identity of the two molecular phenomena by means of which convection of heat and convection of momentum or surface friction were carried on, their dependence on the conditions of motion of the fluid would be the same.

From this it follows that in the case of a uid at temperature t, owing at a velocity v through a pipe whose surface is maintained at a temperature T_s, the heat transmitted per unit area by convection would be

$$R\,\frac{(T_s - t)}{v}\,\sigma$$

where σ is the specific heat per unit mass at constant pressure, and R is the skin friction per unit area. It was pointed out by Reynolds that this value would not be strictly correct, since ultimately the heat is transmitted from the metal to the fluid by pure conduction through a thin film at the walls, so that a factor depending on the conductivity would be needed. It is, of course, possible to investigate the form of this factor by making certain assumptions as to the thickness of the surface film (which is certainly too thin to admit of direct measurement), but a hopeful method of attacking the problem would appear to be by scale model experiments when once the law of similarity has been obtained. To do this, assume that the heat transmission (H) depends on the linear dimensions (l) and surface friction (R) of the pipe, and on the specific heat (σ), density (ρ), thermal conductivity (k), and speed of the luid (v), and on the range of temperature between metal and fluid (θ). The application of the principles then gives

for the law of comparison

$$\frac{R_1}{\rho_1 v_1^2} = \frac{R_2}{\rho_2 v_2^2} \quad \text{and} \quad \frac{k_1}{l_1 v_1 \rho_1 \sigma_1} = \frac{k_2}{l_2 v_2 \rho_2 \sigma_2}$$

and under these conditions

$$\frac{H_1}{H_2} = \frac{l_1^2 v_1 \rho_1 \sigma_1 \theta_1}{l_2^2 v_2 \rho_2 \sigma_2 \theta_2}$$

It would seem, therefore, that in this case an investigation of the problem by model experiments might prove a very fruitful research.

In conclusion it is hoped that the foregoing brief sketch of the application of the principle of similitude to some of the problems of the engineer may tend to correct an impression which is still prevalent that there is only one law of comparison for scale-model tests, and, further, that it may afford some indication of the value of the method in determining when a scale-model test is possible, and the precise conditions under which it must be made if the results are to be reliable.

STRESS DISTRIBUTIONS IN ENGINEERING MATERIALS.

Stress Distributions in Engineering Materials.—Interim Report of the Committee, consisting of Professor J. PERRY *(Chairman)*, Professors E. G. COKER *and* J. E. PETAVEL *(Secretaries)*, Professor A. BARR, Dr. C. CHREE, Mr. GILBERT COOK, Professor W. E. DALBY, Sir J. A. EWING, Professor L. N. G. FILON, Messrs. A. R. FULTON *and* J. J. GUEST, Professors J. B. HENDERSON *and* A. E. H. LOVE, Mr. W. MASON, Dr. F. ROGERS *and* Mr. W. A. SCOBLE, Dr. T. E. STANTON *and* Mr. J. S. WILSON, *to report on certain of the more complex Stress Distributions in Engineering Materials.**

DURING the past year the time of the various members of the Committee has been, to a large extent, taken up by work in connection with the war, and some of the researches carried out by Professor Coker and others, although having a direct bearing on the work of the Committee, cannot, at present, be included in the report.

Papers have been received from Mr. Stromeyer, Dr. Stanton, and Dr. Mason, and are published as appendices.

Mr. Stromeyer submits results of tests in tension, compression, and tension and shear made on a number of steels of different compositions.

Dr. Mason has carried out some experiments with the alternating stress machine he recently designed; these show that when the range of cyclic strain in alternating bending or in alternating torsion is not entirely elastic, the range of non-elastic strain varies largely with change of frequency of cycle. Some experiments have been made to investigate the recovery or apparent recovery that takes place when a piece showing "cyclical permanent set" is allowed to rest. Similar "recovery" has been found, under certain circumstances, after alteration of frequency of cycle, during tests wherein the range of stress was constant throughout.

Dr. Stanton gives a description of a new machine for tests of materials in combined bending and torsion. The general result of his work is a confirmation of Guest's hypothesis for the material used. The Committee ask for re-appointment with a grant of 80*l*.

APPENDIX I.

An Experimental Comparison of Simple and Compound Stresses.

By C. E. STROMEYER.

The following experiments were carried out on 26 samples of mild steel of which the chemical analyses and many mechanical tests have been previously reported. (*Vide* Journal Iron and Steel Inst., 1907 I., 1907 III., 1909 I.; Proceedings R.S., 1915; Trans. Inst. Naval Architects, 1915.)

The object of the present set of experiments was in part to trace a relationship between tension, compression and shear stresses, in order to test the applicability of Guest's law with regard to elastic limits, plastic limits and ultimate strengths, for each of which breakdown points the tension and compression stresses should, according to Guest's law, be equal and twice as great as their combinations: the shearing stresses.

Ultimate Strengths. (TABLE I.)

The ultimate crushing staengths were not obtainable. The ordinary tensile strengths, T, were obtained by the usual method of dividing the original cross-section of the samples into the maximum loads recorded during the tests. The tenacities per reduced section, T_r, were, as the name implies, obtained by dividing the reduced section of the sample, at the point of fracture, into the smallest recorded load at the moment of fracture. On account of the unsteady conditions near the moments of fracture it was not always possible to determine these loads with accuracy. The ultimate shearing strengths, S, were obtained from the torsion tests as explained below. In these cases, too, the unsteady conditions at the ends of the tests interfered with the accuracy. Nevertheless we find that the ratio S/T_r, is fairly constant but rather less than 0.5 as required by Guest's law. The ratios S/T vary from 0.756 to 0.946 and seem to be of no value.

Table I. also contains the estimated ultimate strengths estimated from three formulæ there given. The agreement between the estimated and actual stresses is remarkably good in the case of T. The two other formulæ are of interest because the constants for T_r are approximately twice as great as those for S.

* Report submitted to Section G of the British Association at Newcastle-on-Tyne, September 6, 1916.

TABLE I.—ULTIMATE STRENGTHS.

Samples.	Ultimate Tenacities		Tenacities per Reduced Sections.		Ultimate Shearing Strengths.		S/T.	S/T_r.
	Estimated.	Observed T.	Estimated.	Observed T_r.	Estimated.	Observed S.		
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.		
D	23.78	23.60	40.20	36.57	20.72	21.23	0.90	0.58
A	24.22	24.11	48.16	50.48	27.44	22.00	0.91	0.44
M	25.18	24.90	58.96	58.22 (−)	24.42	—	—	—
X	25.38	24.60	50.52	48.17	23.12	21.05	0.86	0.44
U	25.94	25.30	49.66	53.12	23.29	22.86	0.90	0.43
P	26.33	25.50	54.64	56.74	24.50	24.10	0.95	0.42
S	26.56	26.00	54.24	53.33	24.54	22.90	0.88	0.43
B	27.31	27.40	52.52	56.24	25.10	24.90	0.91	0.44
T	27.33	28.20	54.10	62.62 (−)	24.42	25.72	0.91	0.41 (+)
L	27.40	26.30	56.32	60.56 (−)	25.39	24.40	0.93	0.40 (+)
BB	27.43	27.60	54.32	51.20	24.44	23.34	0.85	0.46
N	27.57	26.27	55.38	58.62 (−)	24.85	23.72	0.90	0.40 (+)
E	27.57	30.60	51.28	58.42 (−)	24.45	23.12	0.76	0.40 (+)
J	27.85	28.10	54.14	67.86 (−)	24.63	24.85	0.89	0.36 (+)
Q	28.81	28.50	54.76	58.77	25.06	29.93	0.91	0.44
V	28.90	29.60	54.70	54.88	24.79	25.00	0.85	0.46
Z	28.97	29.70	55.72	49.33	24.94	24.74	0.83	0.50
F	29.51	28.90	58.78	57.00	27.10	26.60	0.92	0.47
K	29.94	27.80	55.02	54.96 (−)	25.33	25.15	0.90	0.46 (+)
G	30.66	31.30	57.84	60.88	25.85	27.50	0.88	0.45
R	31.26	32.10	60.68	62.80	27.35	27.65	0.86	0.44
W	31.59	31.80	57.48	61.26 (−)	25.90	27.11	0.85	0.43 (+)
H	32.60	33.70	58.40	64.81 (−)	26.65	28.37	0.84	0.44 (+)
C	33.84	33.30	55.76	51.72 (−)	25.73	26.41	0.80	0.51 (+)
Y	37.69	37.40	68.58	66.96	28.97	29.70	0.79	0.44

The above estimated stresses are found by the formulæ:—

$$T = 19.75 + 25\,(C + C^2) + 11.5\,Si + 30\,P + 205\,N - 11.5\,S + 36.5\,As$$
$$T_r = 50.5 + 20\,C + 20\,Si + 40\,P + 200\,N - 80\,S$$
$$S = 22.2 + 9\,C + 6\,Si + 20\,P + 100\,N - 20\,S$$

(−) These stresses may be too high. (+) These ratios may be too low.

TABLE II.—ELASTIC AND PLASTIC LIMITS.

Samples.	Tension.				Compression.		Shear.			
	Elastic Limits.		Plastic		Elastic Limits.		Elastic Limits.		Plastic	
			Limits.	Drops.					Limits.	Drops.
	T_e	T_c	T_p	T_d	C_e	C_c	S_e	S_c	S_p	S_d
	Tons.	Tons.	Tons	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
D	15.5b	16.50b	18.0	18.0	20.0bb	22.63	9.0	11.66	10.9	9.7
A	16.6b	20.90 !	Gradual		14.6b	15.99	8.0	11.87	12.0	10.6
M	16.5 !	—	17.5	17.5	20.2 !	19.61	9.0b	11.79	10.7	9.0(?)
X	16.3b	19.13 !	18.4	18.4	14.1b	12.56	9.4	9.50	10.4	9.4
U	18.81 !	16.61 !	19.7	19.5	—	—	10.5	11.38	11.5	10.4(?)
P	17.45	18.03b	18.1	18.1	—	—	11.0	12.24	11.2	10.4
S	17.2bb	21.31b	21.2	20.9	15.1b	15.80	10.0b	12.30	10.1	9.9
B	17.4 !!	17.84 !	19.0	—	16.9 !	17.25	9.0	12.50	11.6	10.1
T	13.0bb	17.35b	—	—	13.4b	18.77	9.0	12.00	11.2	10.4
L	17.9b	11.11b	21.3	21.2	15.1 !! / 19.7 !!	19.78	11.7	12.42	12.3	11.0(?
BB	19.8b	20.01b	21.2	21.3	14.1b / 18.7 !!	18.66	9.0b	13.20	11.9	10.8(?)
N	11.4bb	13.01b	16.4	16.1	14.6 !	16.80	9.0	10.84	9.2	8.0(?)
E	21.4b	26.08 !!	28.4	28.4	14.5b	18.45	13.6	16.15	14.6	13.4
J	18.7b	17.92b	20.0	20.0	16.6b	17.65	11.8b	13.59	12.9	—
Q	22.9 !	24.58 !	23.2	23.1	17.0bb	20.60	14.6	15.09	14.5	12.6
V	20.0b	24.89 !	23.	23.0	16.7 !	18.38	10.5	15.50	13.4	12.6
Z	20.0 !	21.20b	20.3	20.3	15.6bb	14.94	10.0	12.60	11.8	—
F	19.5 !	20.01 !!	20.2	20.2	16.7b	18.98	10.5b	14.00	12.6	11.3
K	18.8 !	18.46 !	21.0	21.0	18.2 !	20.13	11.3	13.20	12.2	—
G	13.7bb	24.51 !	23.5	23.2	15.1bb	19.58	12.5	14.35	13.6	11.9
R	17.6bb	24.90 !	23.0	22.6	18.0bb	20.68	12.7	16.50	14.2	12.5
W	20.1b	24.38b	23.1	23.1	16.0 !!	18.94	9.0	13.40	12.2	11.0(?)
H	21.3b	24.29 !	24.4	24.4	17.0bb	22.14	14.8	15.50	14.9	12.9
C	17.71	18.00 !	21.0	—	16.1b	18.87	12.0	13.60	12.7	11.3
Y	20.8bb	25.64b	Gradual		25.0 !!	23.12	14.5	15.92	15.7	14.6

(b) Indicates ill-defined limits; (!) well-defined limits; (?) too few observed stresses to make accurate estimates of the "drops."

Possibly with an increased number of experiments the agreement may prove to be a closer one. It should be noted that the influence of nitrogen is about 10 times greater than that of carbon, and that therefore analyses which omit this constituent are valueless for comparisons like the present.

Tables II. and III. deal with elastic and plastic limits on the above lines, but as these limits are badly defined it has seemed desirable to record not only the first indication of curvature in the elastic lines, viz., T_e, C_e, and S_e for tension, compression and shear, but also those stresses T_c, C_c, and S_c when the strain-indicator pointers commenced to creep after the additions of small loads. Under the tension and shearing stresses the material seemed to break down at certain badly defined stresses, which might be called plastic limits T_p and S_p, and sometimes this breakdown resulted in what is generally known as "drop" T_d and S_d, the steelyard dropping without additional loading. Both S_p and S_d have been estimated from the torsion tests as explained in the note at the end of the paper.

As will be seen from Table III. the several ratios vary within the following limits:—

Ratios	S_e/T_e	S_e/C_e	S_c/T_e	S_c/C_c	S_p/T_p	S_d/T_d
From	0.448	0.448	0.497	0.515	0.474	0.472
To	0.908	0.938	0.836	0.876	0.645	0.575

It will be seen that only the last two ratios, and especially the last one, are at all steady. The conclusion may therefore be drawn that Guest's law does not apply to elastic limits as at present defined, but only to the drop stresses. This is perhaps natural, for the drop or minimum stress after the general breakdown is probably the natural resistance of the material, whereas the elastic

TABLE III.

Samples.	Ratios of Shear Limits to Tension and Compression Limits.					
	S_e/T_e	S_e/C_e	S_c/T_e	S_c/C_c	S_p/T_p	S_d/T_d
D	0.58	0.45	0.71	0.51	0.60	0.54
A	0.48	0.55	0.57	0.74	—	—
M	0.54	0.45	—	0.60	0.61	0.51 (?)
X	0.58	0.66	0.50	0.76	0.56	0.52
U	0.56	—	0.61	—	0.58	0.53 (?)
P	0.63	—	0.68	—	0.62	0.57
S	0.58	0.66	0.58	0.78	0.47	0.47
B	0.52	0.53	0.70	0.72	0.60	—
T	0.69	0.67	0.69	0.64	—	—
L	0.66	0.78				
BB	0.45	0.64	0.73	0.63	0.58	0.52 (?)
N	0.79	0.48	0.66	0.71	0.56	0.51 (?)
E	0.67	0.62	0.84	0.65	0.56	0.50
J	0.63	0.94	0.62	0.88	0.51	0.47
Q	0.74	0.71	0.76	0.77	0.64	—
V	0.52	0.86	0.61	0.73	0.62	0.54
Z	0.50	0.63	0.62	0.84	0.59	0.54
F	0.54	0.64	0.59	0.84	0.58	—
K	0.60	0.63	0.70	0.74	0.62	0.56
G	0.91	0.62	0.71	0.65	0.98	—
R	0.72	0.83	0.59	0.73	0.58	0.51
W	0.45	0.70	0.66	0.80	0.62	0.55
H	0.69	0.56	0.55	0.71	0.53	0.48 (?)
C	0.68	0.87	0.64	0.70	0.61	0.53
Y	0.70	0.75	0.76	0.72	0.60	—
		0.62	0.58	0.69	—	—

(?) See footnote, Table II.

limits may have been affected by preliminary strainings and by ageing effects. It should also be mentioned that the changes of curvature of the elastic lines are very much more marked in the tension and compression cases T_s and C_s than in the shearing (torsion) cases, for in these latter it is only the outer fibres of the samples which are affected.

Both in the tension and the compression experiments two strain indicators were used and corrections were made in the final results for eccentricity of pull. These corrections were less than 1.0 ton for the tension tests. Duplicate tests on the same material demonstrated that these corrections are necessary and that the methods adopted are fairly correct.

Note on Shearing Stress Strain Diagrams.

The problem is to determine the shearing stress strain curve from the torsion moment or stress strain curve.

Assume that two similar cylindrical shells of the respective semi-diameters x_1 and x and the thicknesses $d x_1$ and $d x$ are subjected to equal circumferential shearing stresses S, then the respective torsion moments $d M_1$ and dM stand in the relation

$$d M_1/d M = x_1^3/x^3.$$

This relation holds good for a number of concentric cylindrical shells constituting a solid bar, provided of course that the stress distribution is similar in each bar of the respective radii r_1 and r.

$$M_1/M = r_1^3/r^3.$$

Let

$$r_1 = r + d r, \text{ then } M_1 = M (r + d r)^3/r^3 = M \left(1 + \frac{3 d r}{r}\right).$$

Assume that the smaller of the two rods of the radius r receives the addition of a thin cylindrical shell of the thickness $d r$, then its diameter will be the same as the other bar, and if this added cylinder be stressed circumferentially with the stress S, which exists in its original outer fibre, then the torsion moment M_2 for this compounded bar is

$$M_2 = M + 2 \Pi . S r^2 . d r.$$

These two torsion moments M_1 and M_2 would be obtained with one and the same bar if in the first one the shear strain angle at the surface were α_1 and if in the second it were

$$\alpha_2 = \alpha_1 (r + d r)/r = \alpha_1 \left(1 + \frac{d r}{r}\right).$$

Then as $$d \alpha = \alpha_2 - \alpha_1 = \alpha \frac{d r}{r}$$

we may in the above equations replace $d r/r$ by $d \alpha/\alpha$, and combine them as follows :—

$$M_2 - M_1 = d M = 2 . \Pi S r^3 \frac{d \alpha}{\alpha} - 3 M \frac{d \alpha}{\alpha},$$

and we have

$$S = \frac{2}{\Pi r^3} \left(\frac{3}{4} M + \alpha \frac{d M}{d \alpha}\right).$$

As long as the elastic limit of the material of a bar of the diameter $d = 2 r$ is not exceeded, the torsional resisting moment is

$$M = S_s . d^3 \pi /16 = S_s . r^3 \pi /2.$$

If, therefore, from the observed torsion moment we estimate shearing stresses S_s as if the material were perfectly elastic, then the plastic stresses are

$$S = S_s \left(\frac{3}{4} + \frac{1}{4} \frac{\alpha}{M} \frac{d M}{d \alpha}\right).$$

This formula has been used for estimating the plastic shearing limits and drops from the torsion curves. Beyond these limits $d M/d \alpha$ is negligibly small and the ultimate shearing stresses are therefore

$$S = \tfrac{3}{4} S_s.$$

APPENDIX II.

On the Hysteresis of Steel under Repeated Torsion.

By W. MASON, D.Sc.

Recent experiments* have shown that elastic hysteresis becomes rapidly greater with increasing range of stress. At a range of 8.5 tons per square inch, the width of the hysteresis loop for an annealed steel tube, measured in stress, amounted to 15 tons per square inch.

The question arises whether the hysteresis found with stress-ranges which extend beyond what are believed to be the natural elastic limits is or is not of the same nature as elastic hysteresis.

The following set of experiments was one of several made in order to get further information on this point.

A turned and bored hollow specimen (see Fig. 1) of the dead mild steel provided by the Stress Distribution Committee of Section G of the British Association was fixed in an alternating torsion-testing machine wherein the torque, direct and reverse, was applied by a lever which could be operated either by mechanism or loaded by dead weights. The grips holding the ends of the specimen were centred inside ball-bearings, and care was taken to eliminate any friction that might affect the value of the applied torque. The range of the angle of twist was measured by mirrors bolted to specimen at the points shown in Fig. 1. The image of a fixed scale was reflected in turn by each mirror, and was received in a fixed telescope. The mirrors remained fixed to the specimen throughout, and neither the scale nor telescope was moved during the experiments; but if any small displacement of these latter, for any cause, did occur, there could be no effect on the range of torsional strain or width of hysteresis loop observed.

Table IV above explains the scheme of the experiments. The readings in columns *a*, *b*, *c*, *d*, *e* are accurate to within ± 0.01 scale divisions, and the accuracy of the range of strain and of the width of hysteresis loop is certainly well within ± 0.02 scale divisions. The arrangement for observing the torsional strain is intended for measurement of comparatively large ranges of angular twist, and not for the accurate measurement of the elastic hysteresis.

All the readings given in columns *a*, *b*, *c*, *d* and *e* are for the tests in which the torque was applied by weights. During the intermediate runs of repeated stressing at the frequency of 200 per minute, readings were taken of the range of strain, which corresponded very fairly (see table)—up to test No. 7—with the ranges obtained in the dead-weight tests at the same ranges of stress. The former readings, *i.e.*, at 200 per minute, are read to the nearest 0.05 scale division. It will be noticed that there was a distinct increase of range of strain and of width of hysteresis loop during the 36,000 cycles at ± 5.50 tons per square inch; and a larger increase in both of these during the 228,000 cycles at ± 5.62 range. Also at the change of speed after the run of 228,000 from 200 to 8 cycles per minute, the range of strain altered from 6.90 to 7.24; this is an example of the speed effect already found by the author in previous work.*

It appears, then, that for the steel tested there is a limit to elastic ranges of strain in the neighbourhood of ± 5.50 tons per square inch range of stress. A torsion test, made with continuously increasing torque, of another specimen (solid) cut next in order to the specimen of these tests from the same bar of steel, gave a yield point of 9.85 tons per square inch, and a limit of proportionality in the neighbourhood of 5.80 to 6 tons per square inch.

After test No. 8 (see table), a succession of tests at smaller ranges of stress showed the hysteresis loop to be wider even than at the higher ranges of stress of the cycles imposed before the limit to the elastic ranges of stress had been passed. The apparent recovery of elasticity with rest in test No. 15 is presumably the counterpart for alternating cycles of the well-known phenomenon of recovery with rest after overstrain.

The foregoing experiments illustrate the following points :—

At a range of stress—applied by equal direct and reverse torsion—which may be determined with considerably more accuracy than the elastic limit in a static test (*i.e.*, with slowly increasing stress in one direction), the hysteresis increases largely with continued application of the cycles. At a smaller range of stress the increase of hysteresis, if any, is very small and may probably be regarded as an increment of elastic hysteresis. Other of the author's tests have shown that 250,000 cycles of a range of stress somewhat below the above-mentioned limiting range do not cause an increment of hysteresis measurable by the same apparatus as used for the tests cited in this note.

The large increase of hysteresis due to repetitions of a range slightly exceeding this limiting range cannot be regarded as increased elastic hysteresis for two reasons :—1. Because on subsequent application of much less ranges of stress the hysteresis retains an augmented value which appears to be much more than what can be regarded as elastic hysteresis, and (2) the large increase of range of strain is not independent of the speed of cycle; for, as previously shown by the author* (see also test No. 8), a reduction of frequency of cycle gives an increase of range of strain, and *vice versa*; whereas Rowett† has found that the area of the elastic hysteresis loop is the same at low and high speeds within 5 per cent.

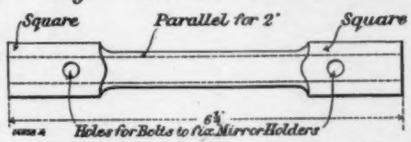
At this limiting range of stress there appears to be a definite impairment of elasticity with repetition of cycle, and the increased hysteresis is most probably the coarser form of hysteresis believed to be due to crystalline slipping.

TABLE IV.

No. of Test.	Conditions of Test.	Range of Stress.	Range of Load on Lever.	Readings on Scale. No Load *a*	+Maxm. *b*	No Load *c*	−Maxm. *d*	No Load *e*	Range of Strain.	Width of Hysteresis Loop.
		Tons per sq. in.	Lb.						Scale divisions $=b-d$	$=a-e$
1	After putting specimen into machine	±5.00	±10.45	12.60	15.51	12.59	9.65	12.56	5.86	0.03
	Specimen given 31,600 cycles at 200 per minute at Range of Stress ±5.00. Range of Strain 5.90.									
2	After 31,600 cycles of ±5.00 tons sq. in.	±5.00	±10.45	12.55	15.50	12.58	9.65	12.55	5.85	0.03
3	Following Test No. 2	±5.25	±10.97	12.55	15.66	12.57	9.50	12.53	6.16	0.04
	Specimen given 12,400 cycles at 200 per minute at Range of Stress ±5.25. Range of Strain 6.15.									
4	After 12,400 cycles of ±5.25 tons sq. in.	±5.25	±10.97	12.56	15.64	12.60	9.51	12.55	6.13	0.05
5	Following Test No. 4	±5.50	±11.50	12.55	15.80	12.59	9.35	12.54	6.45	0.05
	Specimen given 36,000 cycles at 200 per minute at Range of Stress ±5.50. Range of Strain 6.45, but increasing to 6.50.									
6	Test after 36,000 cycles of ±5.50 tons sq. in.	±5.50	±11.50	12.55	15.84	12.61	9.34	12.53	6.50	0.08
7	Following Test No. 6	±5.62	±11.75	12.53	15.87	12.61	9.28	12.53	6.59	0.08
	Specimens given 228,000 cycles at 200 per minute at Range of Stress ±5.62. Range of Strain increasing from 6.60 to 6.90.*									
8	Immediately after 228,000 cycles at ±5.62 tons sq. in.	±5.62	±11.75	12.32	16.21	12.85	8.97	12.31	7.24	0.54
9	Cycles at smaller ranges of stress, following Test No. 8	±4.78	±10.0	12.35	15.58	12.78	9.57	12.40	Loop not	closed
10		±4.78	±10.0	12.40	15.56	12.72	9.57	12.41	6.01	0.31
11		±3.82	± 8.00	12.41	14.90	12.64	10.22	12.49	Loop not	closed
12		±3.82	± 8.00	12.49	14.90	12.64	10.24	12.49	4.66	0.15
13		±2.87	± 6.00	12.49	14.28	12.58	10.82	12.50	3.46	0.08
14		±2.87	± 6.00	12.50	14.27	12.57	10.84	12.50	3.43	0.07
	Specimen allowed 52 hours' rest at zero stress.									
15	After 52 hours' rest	±2.87	± 6.00	12.50	14.25	12.55	10.85	12.50	3.40	0.05

* At the end of this run the range of strain at the frequency of 8 cycles per minute was 7.24.

Fig. 1. TEST SPECIMEN



APPENDIX III.

On the Fatigue Resistance of Mild Steel under Various Conditions of Stress Distribution.

By Dr. T. E. STANTON and Mr. R. G. BATSON.

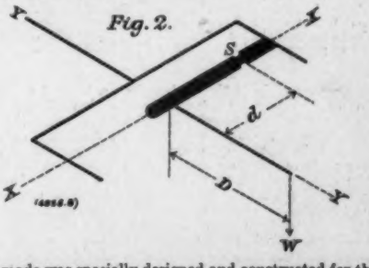
The material on which the experiments described in this report were made was a special sample of mild steel procured for the Committee by Dr. F. Rogers. The ordinary mechanical properties of the steel have been investigated fairly completely, and the results of the tests are given in the report for 1915. It should be mentioned that the specimens used were prepared from the 1–5/16-in. bar, and were not heat-treated before testing. The results of a tensile test on the bar used give results which were practically identical with those obtained by Mr. Cook (see report, 1915, page 160), and were :—

Yield stress	13.5 tons.	per sq. in.
Maximum stress	22.4	„ „
Per cent extension $\left(\frac{l}{d} = 3.5\right)$	49.0	„ „
Per cent. of contraction of area at fracture	70.8	
Modulus of elasticity	29.7×10^6 lb.	per sq.in.

The scheme of experiments was the determination of the fatigue resistance of solid cylindrical specimens subject to rapid alternations of a combined bending and twisting moment of given value and such that the ratio of bending moment to twisting moment could have any desired value between the extreme cases of reversals of simple bending and reversals of simple torsion.

The fatigue-testing machine in which the experiments were made was specially designed and constructed for the purpose of the research in the engineering workshop of the National Physical Laboratory. The general principle of the machine will be seen from Fig. 2 above, which is a diagrammatic representation of the manner in which the

Fig. 2.



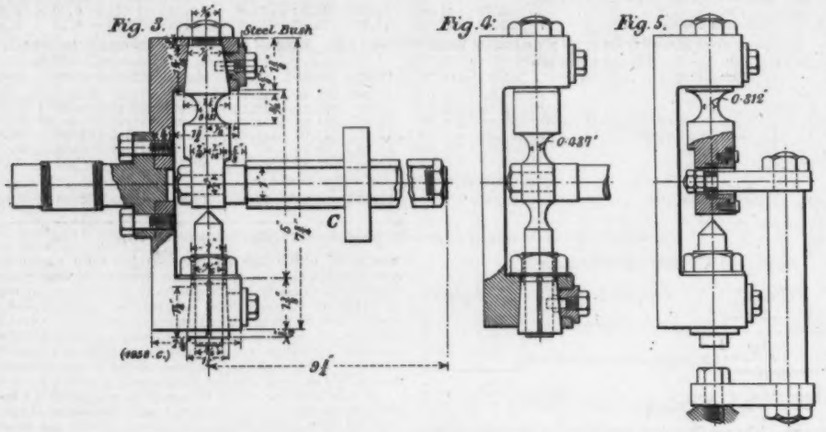
* "Elastic Hysteresis in Steel," F. E. Rowett.—Proc. Roy. Soc. A., Vol. 89, 1914.

* "On Speed Effect and Recovery in Slow-Speed Alternating Stress Tests."—Proc. Roy. Soc., A., vol. 92, 1916.

* Proc. Royal Soc. A, vol. 92.
† Proc. Royal Soc. A, vol. 89.

combination of bending and twisting is applied to the specimen. In the position shown, the cross-section of the specimen S is subject to a twisting moment WD, and to a bending moment W*d*. When the head has turned through 180 deg. the moments will be equal in amount but opposite in sign. When the head has turned through 90 deg. from the position shown the maximum stress will be that due to a bending moment WD plus that due to the direct loading, but as in all cases this stress is below the known fatigue limit of the material under reversals of simple bending, its effect is supposed to be negligible, and the specimen is assumed to be subject to reversals of the combination of bending and twisting moment alone.

The form of specimen adopted is shown in Fig. 3, which represents a plan of the testing head with the specimen and hanger in position. By varying the length of the collar C, and also, if necessary, the position of the neck of the specimen, relative to the axis of rotation of the specimen, it will be seen that the ratio of bending moment to twisting moment can be varied within fairly wide limits.



For the experiments in which the stresses were practically reversals of simple shear, the arrangement described above was not suitable, and the method of making the torsion tests is shown in Fig. 4. In this case it will be seen that the fatigue of the specimen takes place simultaneously over two sections symmetrically placed about the axis of rotation. In the tests the distance of the hanging weight from the axis of the specimen was 8½ in., so that the ratio of the twisting moment to the bending moment was about 40.

TABLE V.

Limiting Fatigue Range of Stress for British Association Mild Steel. Specimens prepared from the 1–5/16-in. round bar and not heat-treated.

Ratio of Twisting Moment to Bending Moment.	Pounds per Square Inch. Tensile Stress on Plane Perpendicular to Axis of Specimen.	Shear Stress on Plane Perpendicular to Axis of Specimen.	Maximum Principal Stress.	Maximum Shear Stress.	
0	±25,000	±12,500	±25,000	±12,500	Experiments made on testing machine of Wöhler type running at 2,000 r.p.m.
0	±25,000	±12,500	±25,000	±12,500	Combined Stress Testing machine running at 2,000 r.p.m.
1.21	±13,600	± 8,000	±17,300	±10,500	Ditto.
1.50	±11,400	± 8,720	±16,100	±10,400	Ditto.
1.83	±11,500	±10,300	±17,550	±11,800	Ditto.
∞	—	±12,600	±12,600	±12,600	Ditto.

For reversals of simple bending, a test of a specimen in an ordinary fatigue-testing machine of the Wöhler type would have been sufficient for the prediction of the fatigue limit. It was considered, however, of fundamental importance to determine if the effect of the reversals of bending produced in this machine were of the same amount as those produced by the continuous rotation of a loaded bar as in the ordinary Wöhler test, and for this purpose a special device was employed, which is illustrated in Fig. 5, which is an elevation of the testing head with the specimen in position. It will be seen that the axis of the load is made to intersect the axis of the specimen, *i.e.*, the torsional moment is made zero, by extending the hanger so as to envelop the head when rotating, and the load is transmitted to the specimen through the ball-bearing in the specimen itself. In this way reversals of simple bending are produced in the specimen, the essential difference between this case and the Wöhler test being that in the former the maximum stress is confined to the axial plane in the specimen perpendicular to the axis of rotation.

The Method of Carrying Out the Tests.

In the ordinary system of testing for the prediction of the limiting fatigue range of stress it is customary to have a fairly large number of specimens, and to commence by imposing a range of stress which will probably cause fracture after a few thousand reversals. The next specimen is then tested under a smaller stress range, and so on until a range is found which the specimen will bear indefinitely. In the present case the cost of each specimen was so considerable that the reverse method to the above was adopted, *i.e.*, a comparatively small range was first imposed, and if after 3,000,000 reversals fracture had not occurred the load was increased by about 5 per cent. and the test carried on. Finally a stage was reached when fracture took place with less than 3,000,000 reversals. A new specimen was then fitted to the machine and tested at what was considered to be the limiting range. In this method the time taken in the series of tests required for the prediction of the fatigue limit is longer than in the former case, but considerable economy in the cost of preparation of specimens is effected.

Results of the Tests.

The results obtained up to the present are given in Table V in the adjoining column.

REMARKS ON THE TESTS.

It will be seen in the first place that the results under alternations of bending in one plane are in agreement with those obtained under alternate bending in rotating planes as in the Wöhler test, so that results obtained in the two types of machines are comparable.

Further, the limiting shear stresses in the pure bending and in the pure torsion tests are seen to be in close agreement.

Finally, although in the three cases of combined stress the limiting maximum shear stresses seem to be, in two cases at least, appreciably below the values for pure bending and pure torsion, the general agreement is so close that further investigation is required before it can be stated definitely that the result indicated is a real one. This investigation is now in hand.

GENERAL CONCLUSIONS.

Although the number of tests carried out up to the present does not justify any general conclusion as to the nature of the criterion for ultimate failure, the general results of the investigation appear to demonstrate that, as a first approximation, Mr. Guest's hypothesis that failure is due to a particular value of the maximum shear stress may be applied to this particular steel.

RENNERFELT AND OTHER STEEL FURNACES.—The Rennerfelt electric steel furnaces are gaining favour. From recent publications it would appear that 64 of these furnaces have already been supplied to order; of these 14 are in the United States. The bronze and ferro-tungsten furnaces built prove the adaptability of the type. The newest furnaces constructed comprise two, one of 3 tons capacity, the other of 6 tons, for making ferro-tungsten. A ¼-ton furnace of 150 kw., for the same purpose, has been delivered to the Tungsten Products Company, of Boulder, Colorado. The Samson Iron Works, of Stockton, California, are going to make steel in their ¼-ton furnace of 225 kw. The Titanium Alloy Company, of Niagara Falls, intend to make bronze in their 100 kw. furnace; the Garline Brass Foundry Company, of Kalamazoo, Michigan, have received a furnace of the same size for the same purpose. The two 4-ton Rennerfelt steel furnaces of the Old Dominion Iron and Nail Works Company at Richmond, Virginia, were started in June, and more furnaces were to be installed there, some larger than those in operation. The electric steel furnaces of the United Steel Corporation are said to have a total capacity of 1,000 tons per 24 hours. Twenty-ton steel furnaces are being started in the Duquesne works of the Carnegie Steel Company and in the Illinois Steel Corporation. These installations would bring the capacity of the electric steel furnaces in the United States up to one million tons per year.

FOREIGN ENGINEERING PROJECTS.

WE give below a few data on several foreign engineering projects taken from the *Board of Trade Journal*. Further information on these projects can be obtained from the Commercial Intelligence Branch, Board of Trade, 73, Basinghall-street, E.C.

Russia.—H.M. Commercial Attaché at Petrograd reports that the official *Bulletin of Laws*, Petrograd, publishes an Imperial Decree authorising the town of Ekaterinodar to conclude a bond loan of 4,055,000 roubles, of which the undermentioned amounts are to be expended as follows:—For paving market places and for construction of shops, 1,046,000 roubles; for construction of various municipal buildings (town hall, fire brigade and police stations, library, chemists' department, lying-in home, &c.), 856,000 roubles; slaughter-house equipment, 331,000 roubles; reclamation of Karasun marsh, 200,000 roubles; purchase and erection of a Diesel dynamo engine at electrical works, 84,000 roubles; plant for hydro-electric power station, 82,000 roubles; and for other town works, 105,000 roubles. The conditions contain the usual clause requiring that in contracts and orders for materials, plant, &c., preference should be given to Russian works, articles and materials, exceptions being granted in each instance by special authorisation only of the Ministers of the Interior and Commerce. Rouble = 2*s.* 1½*d.* (par rate).

Argentine.—The *Boletin Oficial*, Buenos Aires, publishes a Decree approving a project for the carrying out of sanitation and water supply works at a hospital at Allen, Territory of Rio Negro, at an estimated cost of 58,401 pesos currency (about £5,100). Another Decree published in the same issue of the *Boletin* approves projects for works of a similar nature at a hospital at Resistencia, Chaco Territory, at an estimated cost of 75,156 pesos currency (about 6,600*l.*) A further Decree authorises the expenditure of 13,280 pesos currency (about 1,160*l.*) on electric lighting installations at the Resistencia hospital. In each of the above-mentioned cases a public call for tenders for the execution of the works will be made by the "Comisión Asesora de Asilos y Hospitales Regionales," Belgrano 909, Buenos Aires. The *Boletin* also contains a Decree approving an *ad referendum* contract entered into between the "Comisión Asesora de Asilos y Hospitales Regionales" and Juan B. Beltrame, under which the latter will carry out the construction of a hospital in La Rioja (Andine Territory) for the sum of 490,790 pesos currency (about 42,940*l.*). A period of two years will be allowed for the completion of the buildings.

SPITZBERGEN COAL.—A good deal is likely to be heard of the Spitzbergen coal deposits in the near future. A new Norwegian company has been formed for the purpose of carrying on coal mining in Spitzbergen, under the style of the Svalbord Coal Mines, with a capital of not less than 3,000,000 kr., and not more than 5,250,000 kr. The new company, which is being supported by a number of well-known Norwegian business men, has secured the property of the Advent Bay Syndicate, situated south of Advent Valley, and the coal deposits of the Svalbord Syndicate at Green Harbour, both being considered extremely rich in coal. A production of some 200,000 tons of coal annually is reckoned upon. The distance to Norway is about the same as from the Tyne, and the price prevailing at the Tyne is calculated upon; the price of production is said to come out at some 7*s.* f.o.b. Advent Bay or Green Harbour.

INDIAN RAILWAY DEVELOPMENT.—The gross aggregate earnings of all Indian railways in 1914-15 was 40,280,062*l.*, and the working expenses of the year were 21,827,328*l.*, leaving a net revenue for the 12 months of 18,452,734*l.* The return obtained on the capital expended upon open lines amounted in 1914–15 to 5.33 per cent., as compared with 6.19 per cent. in 1913–14. The length of line open at the end of March, 1915, was 35,285 miles, of which 26,232 miles represented State lines. The length of line under construction at the close of 1914–15 was 437 miles. The number of persons carried in 1914–15 was 451,000,000, in round figures; and the weight of goods moved during the year was 81,000,000 tons (also round figures). These totals exhibit a slight reduction, which was principally attributable to the European war. Large additions were made last year to the rolling stock in use upon the Indian systems, the number of locomotives being especially augmented. Striking results have been obtained by the use of superheaters on engines, great savings being effected in both fuel and water consumption, while heavier loads were hauled. Several Indian railways have decided to fit all their main line engines with superheaters. Preliminary trials with oil fuel have been successful, and final trials are in progress, the object being to ascertain the relative cost of oil fuel and coal. The Hardinge Bridge, recently thrown across the Lower Ganges, near Sara, was opened in 1914–15; it is designed to increase the traffic between Calcutta and Northern Bengal and Assam, and it is one of the most interesting and important engineering works in the world. The bridge is 5,900 ft. long, including approaches and river-training works; its cost was 2,400,000*l.* The Cawnpore and Banda broad-gauge line, 76 miles in length, has been constructed to open up the Cawnpore district and a part of Bundelkhand. A metre-gauge line has been constructed by the Jodhpur State administration with the primary object of affording protection against famine. The Southern Shan States line has been opened as far as Aungban; there is now through connection with Rangoon, a distance of 376 miles.